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INTERPRETATIONS OF DIFFICULTY IN HIGH SCHOOL BIOLOGY

by

Valerie Ann Oldham

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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INTERPRETATIONS OF DIFFICULTY IN HIGH SCHOOL BIOLOGY

submitted by Valerie Ann Oldham in partial fulfilment of the requirements for the degree of Master of Education.

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Margaret McKay

Date March 26/82

ABSTRACT

The present research attempts to uncover the meaning of difficulty as experienced by students within the context of high school biology. In contrast to the predominant curriculum orientation which views difficulty as a phenomenon which can be objectively measured and should be eliminated, this study perceives difficulty as a subjective and meaningful experience, a mode of being in the world which is part of everyday life. It is hoped that by investigating the intersubjective meaning of difficulty we, as pedagogues, can gain a better understanding of it and, through that, a deeper sense of our being with children.

The Biology 30 curriculum was selected as the concrete situation within which to explore the notion of difficulty as subjectively experienced and the initial phase of the research aimed to identify the most difficult topic within that curriculum. Questionnaires were administered to six classes of Biology 30 students and to all Biology 30 teachers within the Edmonton Public School System; and data analysis revealed that both students and teachers identified cellular respiration as by far the most difficult topic.

A situational study was carried out in one particular Biology 30 classroom while the topic of cellular respiration was being studied. This involved participant observation, interviews and written accounts, the methodology being devised within the framework of such guiding concerns as the role of the researcher, validity and generalization. All classes were observed by the researcher, who taped them and made field

notes. Taped, semi-structured interviews were carried out daily with a group of four students and with the teacher, Mrs. T. Seven students were interviewed individually once during the topic; eight others kept journals, and, at the end of the topic, all students in the class were asked to give a written description of a difficult experience they had encountered within that context. The tape-recordings of classes and interviews were transcribed every evening; accounts were written up and returned to the participants the following day in order to check their validity.

The material which was gathered during the situational study formed the basis for investigating the meaning of difficulty as experienced in the life-worlds of the biology students. Analysis was carried out at three different and ever-deepening levels. The first level concerns the participants' perceptions of difficulty in relation to the various teacher-directed classroom activities such as working on objectives, lecture and audiovisual presentations, and also investigates the factors which affect their subjective interpretations of difficulty within the context of cellular respiration. Some of the themes that emerge are: complexity, detail and memorization, terminology, chemistry, relevance and interest.

The following level takes a closer look at the notion of difficulty by investigating some of the phrases used by participants to describe their experiences. The majority of these phrases, such as clearing up, grasping, clicking and being lost, are metaphorical, and some effort is made to explore what they reveal about the experience of difficulty within the context of the Biology 30 curriculum. The sense of frustration which, for many, accompanies encounters with difficulty is then explored,

and reveals the notions of trying, losing hope and giving up.

Finally and most importantly, difficulty is viewed as a mode of being in the world which is ever-present, at least horizonally, as possibility. Its significance in life is considered and it is suggested that it be perceived as life's way of challenging us to be virtuous and grow beyond ourselves. Thus difficulty both gives us a sense of what life is and beckons us ever onward towards the realization of the not-yet.

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"If only we arrange our life according
To that principle which counsels us
That we must always hold to the difficult
Then that which now still seems to us
The most alien will become what we
Most trust and find most faithful."

Rainer Maria Rilke

CHAPTER I

INTRODUCTION TO THE QUESTION

Search for the Question

Appropriately enough, choosing a thesis topic was in itself a difficult task. I seemed to go through cycles of elation and rejection, initially becoming most enthusiastic about the possibilities of a particular project, only to reject it as unsatisfactory a few days or weeks later. This was becoming quite a depressing experience and I wondered if I would ever be able to make a final decision.

One day as I was in the library skimming through some journals, seeking new ideas, I came across an interesting article reporting research done in Scotland on "Isolating topics of high perceived difficulty in school biology." As a biology teacher myself it seemed that finding out which topics students and teachers perceived to be the most difficult was an important project. Reflecting on my teaching experience, genetics immediately came to mind. It had seemed that the pupils almost had a 'mental block' against it and no matter how hard I tried to show them that it was not difficult (because for me it was not) and no matter how well they did on tests, they still thought it was most terribly difficult. Yes, I thought, this is a significant question.

The more I thought about it the more sense it made to me to look into the notion of difficulty as experienced from the students' points of view; and yet just to identify difficult topics within a curriculum seemed

insufficient. The authors of the paper I had seen had proceeded to investigate particular topics in order to find out exactly where the problems lay and how they could be remedied. This was in line with the general orientation since most of the research that has been done on difficulty in high school science concerns concept development and course content. Thus one route came into view, and I could feel it attracting me, perhaps not least because it fell within a paradigm with which I was quite familiar.

At the same time, however, I began to wonder more about what students mean when they describe something as difficult and what we as teachers mean when we say something is difficult either for ourselves or for our students. As a teacher, how often I had seen what seemed to be indications of this in my students' blank stares, puzzled looks, requests for re-explanation, questions and more questions, statements they did not understand. From such clues I sensed that they were experiencing this thing called difficulty. In my graduate work I, too, had experienced it: difficult assignments, difficult exams, difficult papers to read. I recalled one particular assignment with which I had had many problems. While I was still writing it I told the professor that it was the most difficult assignment I had ever had to do. He appeared to see my point, and I wondered later "What did I really mean by that?" and "What did he understand me as saying?" It seemed that in our everyday lives we as teachers and as students come to encounter and through that to know difficulty; we speak of it to one another in various ways and yet we never truly question what it is.

And so I decided that it was this aspect of difficulty that I wanted to study—the meaning of difficulty and what it is like to experi-

ence it in a pedagogic sense, both inside and outside classrooms but within an educational context. Thus this thesis represents an attempt to view difficulty in a new light, to see it as an experience in time, a way of being in the world which is part of our everyday lives, rather than as something that can be objectively measured and eliminated. By turning to and describing the experience of difficulty, it is hoped that its meaning can be elucidated so that upon reflection we as pedagogues can come to a better understanding of it and through this a deeper sense of our being with children.

It may be helpful at this point to consider for a moment the etymological roots of the word 'difficult.' It comes originally from the Latin words 'dificile' and 'dificultas,' meaning respectively 'difficult' and 'difficulty.' 'Dificile' stems from 'di-facile,' 'di' denoting negation and 'facile' meaning 'easy;' hence the translation would be 'not easy.'

Dictionary definitions of difficult include hard to do or deal with or practise or understand (Pocket Oxford Dictionary, p.231); not easy, arduous, perplexing, not easily managed (Webster's Dictionary, p. 220); and its antonyms are given as easy, plain, straight, simple and lucid.

It appears that little has been written directly on difficulty, but it is interesting to consider Rainer Maria Rilke's book, entitled "On Love and Other Difficulties", in which he expresses the view that difficulty is a natural and to-be-expected mode of being in the world. Rilke feels that most actions and experiences are indeed difficult in some way . and he gives as examples love, sex, the writing of poetry and through these the very living of life. He writes:

> "But they are difficult things with which we have been charged; almost everything serious is difficult and everything is serious." (p. 33)

It is towards such a notion of difficulty that I find myself increasingly drawn, difficulty as a common experience in everyday life, the meaning of which transcends the particular context in which it takes place. However, in order to attempt to elucidate the meaning of difficulty, it is necessary to turn to a concrete situation, in this case a biology curriculum, and work from this towards a deeper, ontological meaning. This thesis, therefore, represents an interest both in difficulty and in a high school biology curriculum since the one is the means through which to ask the deeper question of the other.

Review of the Literature

It appears from the relevant literature that the notion of difficulty within the school situation is usually interpreted as difficulty in understanding and is closely related to concept learning and attainment. The majority of such studies concern conceptual difficulty in terms of structuralist theory, and specific preconceptions and misconceptions held by students. A number of studies have also been carried out into subjective perceptions of difficulty of various materials and curricula in the area of high school science. Since the above-mentioned research concerns the notion of difficulty within the context of high school science, it is somewhat related to the problem at hand and will be elaborated on further.

Difficulty in Terms of Structuralist Theory

Shayer (1974) has investigated the conceptual demands of the Nuffield ordinary level biology course in terms of Piagetian theory. The mean chronological ages of pupils throughout the five year course were computed as were their levels of cognitive development. Each chapter of

the five textbooks was then analyzed in terms of the minimum conceptual stage for pupil interest and appreciation of course structure. On the basis of this, the majority of topics and materials were found to require concrete operational thought (IIB) for pupil interest, while others such as respiration, photosynthesis, evolution and genetics require formal thought (IIIA). All were estimated to require formal operational thought (IIIA) for pupils to appreciate the development of the course structure. Shayer (1974) concluded that some of the content of this course was not suitable for the average pupil since "the level of thinking is at least a year too previous at all points" (p.385). He suggested modification of content either by omission or changing its position, in order to overcome such difficulties.

In a somewhat similar way, Lawson and Renner (1975) have investigated the understanding of concrete and formal operational concepts by secondary science pupils. Random samples of biology, physics and chemistry students were selected from one high school and their levels of cognitive development were assessed using four Piagetian tasks and written multiple choice tests. The biology sample comprised 51 students whose mean age was 15.4 years, and results from the tests showed that 65% of these pupils were operating entirely or partially at the concrete level, the remainder as formal IIIA or transitional formal thinkers. From this, Lawson and Renner (1975) conclude:

> "The results of this investigation suggest that a substantial portion of secondary school science subject matter may not be suitable in terms of the intellectual level of the learner." (p.356)

Both these studies make use of Piaget's theory of cognitive development in order to explain difficulty in terms of conceptual learning.

The authors impose a particular notion of rationality on the study, in this case that if students have not reached a particular stage of intellectual development this may account for certain concepts being beyond their capabilities and thus explain their difficulties. This approach does not seek understanding of what difficulty is but rather provides a logical explanation to account for students' conceptual difficulties. It aims furthermore to suggest changes in course content that may eliminate these difficulties.

The Effect of Student Preconceptions on Difficulty

Deadman and Kelly (1978) and Kargbo, Hobbs and Erickson (1980) have investigated student preconceptions about the biological topics of evolution and heredity. Deadman and Kelly (1978) worked with secondary school boys aged 11 - 15 years, interviewing them in two consecutive years for approximately half an hour on their understanding of evolution and heredity. The interviews were taped and transcribed, the material from them being used to elucidate students' ideas and beliefs. Based on this, Deadman and Kelly (1978) proposed a set of conceptual schemes that they hoped would provide the means to overcome learning difficulties in this area by taking into account the ideas pupils bring with them to the classroom, for example, Lamarckian interpretations and inadequate understanding of probability.

In a similar manner, Kargbo, Hobbs and Erickson (1980) investigated the ability of 6 - 13 year old students to distinguish between environmentally-produced and inherited characteristics through the use of Piagetian-type interviews. A wide range of beliefs was found between subjects of all age levels and it was evident that the children had developed

their own theories or 'alternative frameworks' to explain the various forms of phenotypic traits exhibited by organisms around them (p.145). Kargbo et al. (1980) suggest that appropriate curriculum materials need to be developed which take children's intuitive beliefs into account since, if there is a large discrepancy between these and the concepts presented by the teacher, difficulties may ensue. Again, therefore, the intent of this research appears to be the elimination of difficulty as measured in terms of concept understanding.

Difficulty as Evidenced by Student Misconceptions

A number of research studies have investigated specific student misconceptions in high school science including biology. The majority of these, such as those by Kuethe (1963), Doran (1972), Za'rour (1975) and Brumby (1979), utilize methods of objective evaluation in the form of achievement tests to identify common misconceptions, misinterpretations or partial interpretations of concepts after instruction. They could therefore be described as concerning difficulty as measured against external criteria of correctness. For example, the study carried out by Brumby (1979) shows the low proportion of first year university students who understood the concept of natural selection and its significance in evolutionary theory. This was measured by a test involving both multiple choice and written answers, the results of which showed that, of a possible total of six points, 59% of the students with advanced level biology and 86% of those without, scored between zero and two points. Through their answers Brumby (1979) was able to reveal the nature of particular misunderstandings. She states about natural selection:

> "Teachers need to re-teach this concept in order to overcome students' misconceptions which block their understanding of the basic concepts determining the continuing evolution of life on earth." (p.122)

In this way such studies essentially measure what students do and do not know and thereby identify areas of difficulty in terms of specific content, the intent being to eliminate such problems.

Perceived Difficulty in High School Science

Whereas the above studies focus mainly on difficulty as measured by objective means, there are a number which are concerned with more subjective perceptions of difficulty in high school science. Kelly and Monger (1974) carried out an evaluation of the Nuffield ordinary level biology course materials and their use, from the viewpoints of both students and teachers. Questionnaires were sent to senior biology teachers in over two hundred schools to examine the ways in which materials were used and to assess the suitability of the content and teaching methods in the texts. Discussions were also carried out with biology teachers in 51 schools, and 1700 pupils in these schools filled in short questionnaires about the interest and difficulty of the different chapters of the textbooks they had used that year. Table I shows the chapters identified as difficult by both students and teachers. It is evident that some but not many were described as difficult by both samples.

Reasons given by teachers to explain these difficulties fell into two categories: those concerned with practical work, and others. The former included: inconclusive and unsatisfactory results, too many investigations, investigations too long, wrong time of year. Students also cited unsatisfactory results and sophisticated experiments as contributing to their perceptions of difficulty. Other causes of difficulty were given

by teachers as: many new terms, complex vocabulary, amount of detail, sophisticated concepts, and problems with math. Students concurred regarding the vocabulary and math, and also mentioned problems with formulae and equations, unclear explanations in the text and a sense of being rushed through the course.

TABLE I

Chapters of Nuffield O Level Biology Materials Identified as Difficult

Book	Teachers	Students	Title of Chapter	Topic
Book I	Ch. 1 Ch. 2	Ch. 1	The variety of life Investigating living things	Classification
Book II	Ch. 5 Ch. 6 Ch. 7	Ch. 5	Shapes, sizes and movements Size and surface Movement in plants and animals	Shapes, sizes and movements
Book III	 Ch. 11	Ch. 1 Ch. 4 Ch. 6	A closer look at gas exchange Food and problems of a balanced diet Studying the human digestive system Reaching the habitat	Gas exchange Heterotrophic nutrition
Book IV	Ch. 1 Ch. 2 Ch. 3	 Ch. 6	Becoming established in a habitat Community and succession Activity in the soil Ions as plant food	Ecology Autotrophic nutrition
Book V	Ch. 5	Ch. 5 Ch. 10	How do genes work? Mathematical model of gene pool	Genetics

Note: From Kelly & Monger (1974: 480-481)

It is noticeable that in this study by Kelly and Monger (1974) most of the chapters described by students as difficult were also classified as uninteresting, the human digestive system being the only exception to this (pp.481-2). Reasons given by students to explain a lack of interest include: insufficient and unsatisfactory experimentation, inability to see the purpose of practical work, irrelevance to biology due to involving too much math and/or chemistry, too many facts, difficult vocabulary and too much time on the topic. It can be seen that some of these are the same as those given to account for difficulty. In contrast to this, topics that were perceived as interesting concerned the human body and enabled students to find out how it functions; they were of practical use and relevance to everyday life and involved quick successful practical work. This research by Kelly and Monger was thus concerned with difficulty as subjectively experienced by students and teachers.

Johnstone and his associates at Glasgow University have carried out three studies to investigate students' perceptions of difficulty in Scottish Certificate of Education science curricula (Johnstone 1974; Johnstone and Mughol 1976; Johnstone and Mahmoud 1980). Questionnaires were administered to various populations and respondents were required to categorize a number of topics or concepts as easy, average, difficult or never taught. Difficulty was defined for subjects in terms of time and effort required for understanding. Table II compares the populations, sample sizes and instruments used in each study. It is evident that the wording of the categories used to describe the topics or concepts varied slightly from study to study, although the basic idea remained the same: understood first time, understood with effort, not understood and not taught. However,

TABLE II

Comparison of Studies by Johnstone et al.to Identify Topics of High Perceived Difficulty in High School Science Curricula

Curriculum	Ordinary Grade Chemistry (1974)	Ordinary Grade Physics (1976)	Higher Grade Biology (1980)
Population and sample sizes	Post O grade N=2000 Ord'y National Cert. N= 800 6th year studies N=2400 1st year university N=1000 Teachers N= ?	Pre O grade N=499 Post O grade N=414 1st year university N= 83	Pre H grade N=166 1st year university N=167 Teachers N= 50
Instrumentation	Questionnaire	Questionnaire Multiple choice test	Questionnaire
Categories	A. Easy—understood first time with little effort. B. Difficult—requiring considerable effort but was eventually understood. C. Never understood—never grasped and would have to be re-taught. D. Never studied	A. Easy to understand—I got the idea first time. B. Difficult to understand—I now understand but I had difficulty doing so. C. Never understood—even after several attempts I still did not understand it. D. Never studied	A. Easy—I understood it first time. B. Average—I had to work at it but I now understand. C. Difficult—I have worked at it but I still don't understand it. D. I was never taught this topic.

(continued)

Table II (continued)

Difficulty Indices	C x 100 / Total - D	(B + C) x 100 / Total - D	C x 100 / Total - D
Topics of Greatest Perceived Difficulty	Ionic and covalent bonding Writing formulae and equations Electron transfer in redox reactions Calculations to find molarity Ion-electron half equations Hydrolysis of carbohydrates Formation of esters	Pressure Conservation of momentum Energy and power Heat transfer, latent heat Ideas associated with wave motion Current (a.c. and d.c.) Resistance	Osmosis and water potential Chemical energy, ATP, ADP Water balance and osmoregulation Chemistry of respiration Chemistry of photosynthesis

in each case difficulty was clearly defined and difficulty indices were computed on the basis of this. The aim of such studies appears to be the identification of areas or topics of high perceived difficulty so that the causes of the difficulty can be discovered and investigated in order to eliminate the students' problems.

Results from all studies showed that the difficulty indices, computed as shown in Table II, decreased as educational level increased, that is, the percentage of school students who described a topic as difficult was more than the percentage of university students. In the physics study (Johnstone and Mughol 1976), a multiple choice test was administered as well as the questionnaire. The intent of this was to investigate the relationship between subjective perceptions of difficulty as experienced and difficulty as objectively measured. Four possibilities therefore arose: that students who described the topic as easy would do either well or poorly on the test and that students who described the topic as difficult would either perform well or poorly. The results of Johnstone and Mughol (1976) can be represented in the following way, where the figures shown are percentages:

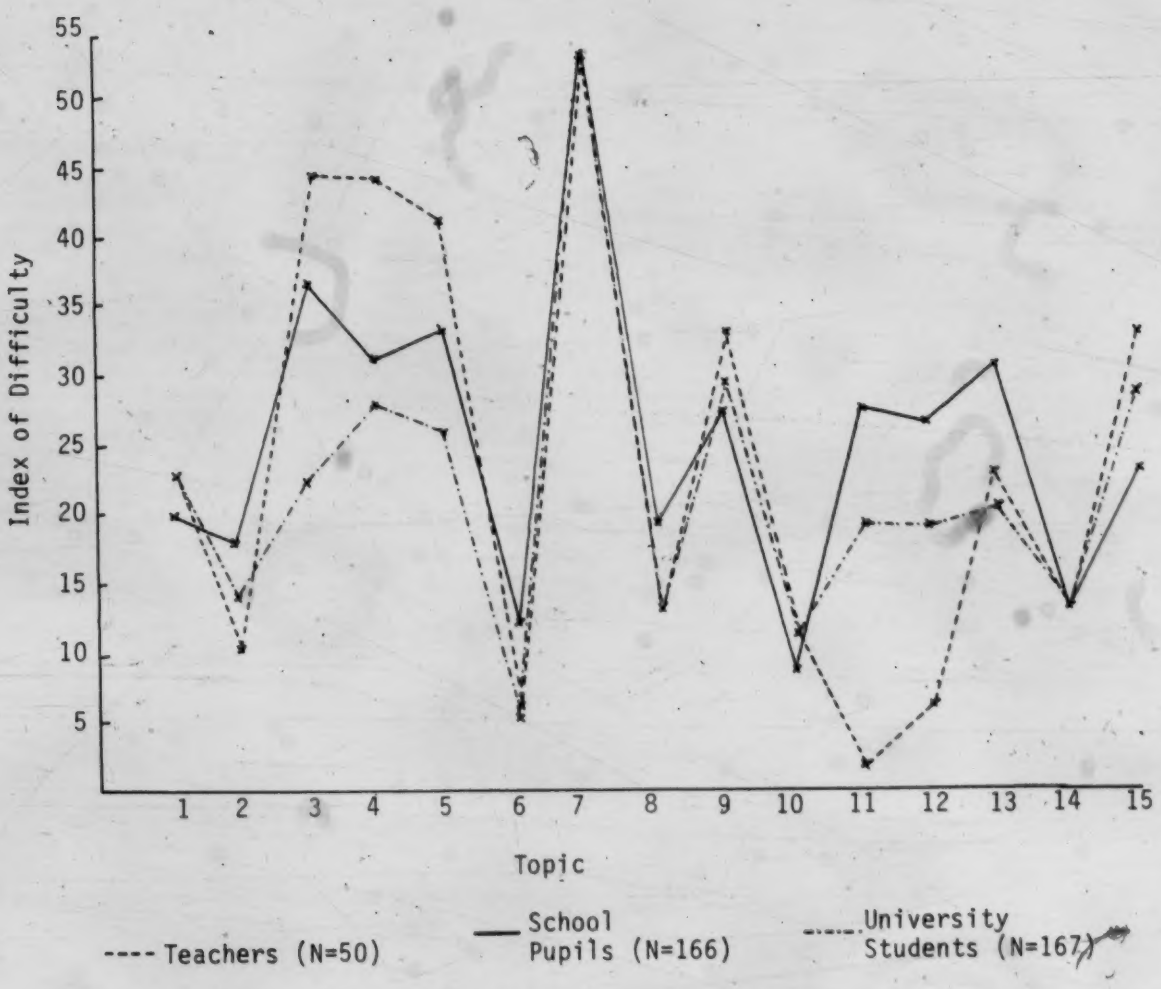
		Subjective: Easy	Subjective: Difficult
Objective	Difficult	0	?
	Easy	?	16

The data given were incomplete and there was no explanation as to what test results were classified as showing that students found the topic easy or difficult. Results showed that there were no students who felt a topic to be easy but performed poorly on the test, whereas approximately 16% of the students perceived a topic as difficult but performed satisfactorily. The authors attributed this to superficial testing, although the present researcher is of the opinion that such devices are investigating very different aspects of difficulty, namely difficulty as subjectively experienced and difficulty as objectively measured. Although there may be a correlation between the two, it seems possible that a student could encounter great difficulty but eventually master the concept and hence perform well on a test. When Johnstone and Mughol (1976) computed correlations between the difficulty index of a concept and its mean facility value on the test, figures of -0.36, -0.45 and -0.70 were obtained for the various populations. Thus some indication was given of an inverse relationship between subjective perception and objective measurement of difficulty.

Johnstone and Mahmoud (1980) performed a study with the Scottish Certificate of Education higher grade biology curriculum. A list of fifteen topics was formulated directly from the syllabus and school pupils, university students and teachers were asked to categorize these as easy, average, difficult or not taught. Difficult topic was defined by "I have worked at it but still don't understand it." Figure I shows the three sets of results based on difficulty indices computed as described in Table II. It is evident that the perceptions of the different populations with regard to the difficulty of topics is fairly similar. Topics of greatest perceived difficulty were osmosis and water potential, chemistry

FIGURE I

Perceived Difficulty of Topics in S.C.E. Higher Grade Biology Curriculum



Topics

1 DNA and RNA
2 Cell structure and cell division
3 Chemical energy, ATP, ADP
4 Chemistry of photosynthesis
5 Chemistry of respiration
6 Gas exchange
7 Osmosis and water potential
8 Role of kidney
9 Water balance and osmoregulation
10 Reproduction and growth
11 Hormones
12 Gametes
13 Genes
14 Evidence for evolution
15 Mechanism of evolution

Note: From Johnstone & Mahmoud (1980: 165)

of respiration and photosynthesis, genetics and evolution. Examiners' reports also identified these as areas of weakness.

Table III shows the rank orders of the various topics for teachers and school pupils, as computed on the basis of the difficulty indices. It is evident that there is a large degree of similarity between the two, the rank order correlation being 0.70 which is significant at the .01 level. Rank order correlations between the other populations were computed as .77 and .83. Thus it appears that there were very close relationships between the perceptions of school pupils, university students and teachers regarding the difficulty of topics in the higher grade biology curriculum.

Various issues arise with regard to this study. Firstly, although the topics were apparently taken directly from the curriculum guide, there appears to be a certain amount of overlap. Gametes is a separate topic from reproduction and growth, genes from DNA and RNA, chemical energy, ATP, ADP from the chemistry of respiration. Thus, the use of those particular fifteen topics seems questionable since although they might be listed separately or as sub-headings in the syllabus it is very doubtful that they could ever be taught in this way.

Secondly, it is evident from the examiners' reports that, unless there had been some recent changes, not all topics in the curriculum were included on the questionnaire for categorization. Ecology is an example of this. It is mentioned by the examiners as a problem area but was omitted from the questionnaire. Since there was an inbuilt mechanism for dealing with topics not yet studied, all topics should have been included.

TABLE III

Rank Order of Difficult Topics in S.C.E. Higher Grade Biology Curriculum

Students	Teachers
Osmosis and Water Potential	Osmosis and Water Potential
Chemical Energy, ATP, ADP	Chemical Energy, ATP, ADP
Water Balance and Osmoregulation	Chemistry of Photosynthesis
Chemistry of Respiration	Chemistry of Respiration
Chemistry of Photosynthesis	Water Balance and Osmoregulation
Genes	Mechanism of Evolution
Hormones	Genes
Gametes	DNA and RNA
Mechanism of Evolution	Role of Kidney
DNA and RNA	Evidence for Evolution
Cell Structure and Cell Division	Cell Structure and Cell Division
Role of Kidney	Gas Exchange
Evidence for Evolution	Reproduction and Growth
Gas Exchange	Gametes
Reproduction and Growth	Hormones

Note: From Johnstone & Mahmoud (1980: 165)

Finally, it is interesting to note that in all the above three studies difficulty was clearly defined for respondents in terms of time and effort required for understanding. Johnstone and Mahmoud (1980) could be said to have imposed their idea of difficulty on respondents rather than allowing them to define it in terms of what it means for them. For example, the definition of difficult as 'I have worked at it but I still don't understand it' (p.163) precludes the possibility of having found a topic difficult but having eventually mastered it. This notion of difficulty also assumes that ideas are either understood or not understood, that there is a clear line between the two rather than degrees of understanding. The present author finds such an imposed meaning of difficulty, defined by someone other than the subjects themselves, contrary to her research interests since it assumes that the researcher's a priori conceptualization is adequate and appropriate.

The studies of Johnstone et al. therefore succeeded in identifying topics of high perceived difficulty in order that these could be further investigated to try and elucidate the cause of the difficulties. Johnstone and Kellett (1980) write:

> "No particular theoretical stance was adopted lest the work should be prematurely coloured or skewed." (p.176)

However, following further research into specific concepts, Johnstone and Kellett (1980) propose a theory to explain why certain topics and concepts are perceived in this way. This involves a previous theory concerning the ability of short term memory to store and retrieve a limited number, 7±2 chunks of information. A chunk is defined as "what the observer perceives or recognizes as a unit, for instance, a word, a letter or a digit." (p. 176)

Johnstone and Kellett (1980) claim that areas of high perceived difficulty in school science are high information situations which require students to be able to form chunks. If due to poor conceptual understanding the student cannot see the relevant chunks or if the number of manageable chunks is exceeded, he or she will have difficulty in learning the material. On the basis of this, the authors recommend that teachers operate in low-information situations wherever possible, developing concepts gradually and initially providing pupils with rules of thumb to help them overcome the amount of information involved. Johnstone and Kellett (1980) hope that these methods will remedy pupil misunderstandings and hence pupil difficulties; thereby leading to more effective learning.

The Researcher's Position

In conclusion to the review of literature, therefore, it is evident that the dominant orientation of research into difficulty in high school science involves an attempt to provide causal explanation and suggest ways in which difficulty can be overcome in order to promote more effective learning. Most of the studies described above are concerned with using structuralist theories or pupils' alternate frameworks to account for difficulty as measured in terms of understanding particular content. The studies by Kelly and Monger (1974) and Johnstone et al. (1974; 1976; 1980) appear to move away from this by investigating subjective perceptions of difficulty from the viewpoints of both students and teachers. However, it seems that the intent is similar to that of the more objective studies since the identification of difficult topics leads

to further research which aims to explain conceptual difficulty and provide alternatives for overcoming or eliminating it.

The interests underlying all these studies place them within the dominant positivistic or empirical-analytic tradition of educational research with its emphasis on explanation, prediction and control (Aoki, 1979). They seek nomothetic knowledge in the form of cause and effect relationships and generalizations that aim to explain rather than understand difficulty. The assumption underlying this approach is that if the causes of difficulty can be discovered, appropriate action can be taken to eradicate learning problems.

In contrast, the present work falls within the situational-interpretive tradition (Aoki, 1979) since it aims to re-search the notion of difficulty by turning to its meaning and significance in the lives of those who experience it. Merleau-Ponty (1962) describes an individual as "condemned to meaning" since he is constantly involved in interpreting and making sense of the situations in which he finds himself. High school biology students are no different as they interpret what goes on in the light of their own interests and intents. Since each individual has what Schutz (1970) describes as a unique biographical situation, although two people may live through the same situation, their interpretations of it will vary. Students therefore will have different perceptions of what difficulty means and what it is like to experience difficulty in their everyday lives and yet, since the world is essentially intersubjective in that others are also present and those others appear to be experiencing the same world as us, it seems reasonable to expect that there are some aspects of the meaning of difficulty that are intersubjectively shared and communicated. On the basis of this, one intent of the present research

is to investigate the intersubjective meaning of difficulty and its significance in the life-worlds of those who experience it.

Re-searching difficulty in this way, therefore, necessitates, in the words of Husserl (1960), turning "to the things themselves," to the alingual and pre-reflective world" which precedes objective knowledge and of which knowledge always speaks." (Merleau-Ponty, 1964) In the present case, this is the everyday world of the classroom where students and teacher share the same vivid present, grow older together. Embedded within this situation is the taken-for-granted and oftimes unnoticed experiencing of difficulty which normally remains unquestioned and hidden. By making difficulty problematic and approaching it from the subjective viewpoints of those experiencing it within the context of a biology curriculum, the present author hopes to be able to try and loosen the grounds of its meaning, thereby bringing that meaning out of the hiddenness it encounters by being so much a part of the situation.

It is hoped to gain a Verstehende grasp of classroom reality that will lead towards a deeper intersubjective understanding of difficulty as a mode of being in the world. With regard to the practical dimension of such an attempt, van Manen (1978) writes:

> "A description may be seen as practical in a communicative sense if it contributes to the deep structure of our understanding of a certain phenomenon." (p.62)

Phenomenological description can thus be used as a basis for personal reflection in the hope that this may lead to some form of praxiological action aimed at improving our lived world through more meaningful communication.

CHAPTER II

METHODOLOGY

Both quantitative and qualitative research methodologies are used in the present study in order to investigate the notion of difficulty in high school biology. The first phase of the research involved the identification of the most difficult topic in the Biology 30 curriculum, as perceived by students; and the most appropriate way to achieve this was to administer a questionnaire to a number of such students. The questionnaire therefore aimed to obtain an indication of students' subjective experiences of difficulty and to isolate the context in which the meaning of difficulty could be further investigated. In order to compare students' and teachers' perceptions of difficulty, a similar questionnaire was sent to Biology 30 teachers.

Following this phase, a situational study was carried out in one classroom in order to try to unearth the meaning of difficulty and what it is like for students to experience difficulty. Since the interest at this point was in students' and teacher's interpretations and sense making of classroom events, the researcher spent some time in that situation observing and interviewing. As meanings and significance are not observable phenomena, qualitative methods were deemed the most suitable since they enabled the researcher to share in the situation and talk to participants about their subjective and intersubjective perceptions of difficulty.

It is evident, therefore, that the two phases of the research represent two very different approaches in terms of methodology and underlying

assumptions. Each has an important role to play in the present study and and contributes to an elucidation of the notion of difficulty in its pedagogic aspect. Rothe (1980) has, in a somewhat similar fashion, used both qualitative and quantitative methodologies in a study concerning the counselling program in New Westminster; although in that case the approaches were used simultaneously whereas the present research utilizes them sequentially. Nevertheless, both studies use two essentially different yet complementary approaches, in the terms of Aoki (1979) one empirical-analytic, the other situational-interpretive. Such a combination of methodologies best suited the research needs and produced deeper insights than one alone could have provided. They were therefore both required and worked together to answer the research questions since, in order to investigate the meaning of difficulty, a particular context had to be identified. Quantitative methods in the form of a questionnaire were most suitable for achieving this whereas qualitative methods such as participant observation and interviews were more appropriate for attempting to disclose the meaning of difficulty within a specific situation.

Quantitative Methodology

Limitations and Delimitations

Having decided to study the phenomenon of difficulty through high school biology, a curriculum had to be selected to provide the context. Previous research by Shayer (1974) as well as personal experience suggested that genetics and evolution might be viewed as difficult by students. These are part of the Biology 20 curriculum but on discussing the issue with a number of biology teachers at Alberta Education Research Department

it became apparent that a number of units officially in the Biology 10 curriculum are sometimes taught in the 20 and vice versa. This would have made the formulation of a questionnaire to identify the most difficult topic problematic since not all students would have studied the same material. An alternative was to deal with all three curricula, either administering questionnaires to Biology 10, 20 and 30 students at the end of their respective programs, or to Biology 30 students only, asking them to rate units from all three courses. With regard to the latter suggestion, some concern was expressed with validity. Finally, the decision was made to deal solely with the Biology 30 curriculum. Although it did not include such topics as genetics and evolution, the subject matter was broad. It was also realized at this point that any curriculum could have been used to provide the context within which to investigate the meaning of difficulty.

A decision was also made to delimit the population for the study to those students and teachers within the Edmonton Public School System in 1981, and to involve six classes of Biology 30 students with a projected total of around 150, and all the Biology 30 teachers. The students who answered the questionnaire comprised six classes from six different high schools. The number of students per class ranged from 15 to 30, the total being 140. A sample of this size was deemed adequate to identify the topic of greatest perceived difficulty in the Biology 30 curriculum for the purposes of the present research.

Although the present study is concerned primarily with difficulty as subjectively experienced by students within the Biology 30 curriculum, it might also have been interesting to examine the relationship between

this and difficulty as objectively measured by Alberta Education achievement tests. This, however, proved to be inadvisable due to the small number of test items on any particular topic as well as the problem of differentiating between what students genuinely had difficulty with and what was a function of question difficulty.

Formulation of Student Questionnaire

A questionnaire was developed according to the model proposed by Johnstone and Mahmoud (1980), its aim being the identification of the most difficult topic in the Biology 30 curriculum so that the meaning of difficulty could be investigated within that particular context. Fourteen topics were listed, having been taken directly from the curriculum guide (see Appendix I). Under each title, some indication was given of sub-topics, particular aspects of the topic that would have been studied. For example, cellular respiration included: energy release, anaerobic respiration, aerobic respiration, chemistry of respiration, ADP, ATP, phosphorylation, citric acid cycle and importance of cellular respiration.

Respondents of the questionnaire were to rate each topic as either easy, average, difficult or never taught, but in contrast to the study by Johnstone and Mahmoud (1980), no definitions were provided of these terms. This decision was taken in order to allow the subjects to use their own meanings rather than imposing the researcher's a priori conceptualizations on them. The questionnaire also required pupils to state their sex and the high school science courses they had taken and were currently taking. The reason for this was in order to investigate factors affecting perceptions of difficulty. In addition to rating the fourteen topics as easy, average, difficult or not taught, students were asked to rank order what

they felt were the five most difficult topics and to explain the criteria they used to do this (see Appendix II for student questionnaire).

Planning for Questionnaire Administration

The optimum time to administer the questionnaire was as near the end of the curriculum as possible so that pupils would have completed most if not all of the topics. Permission was obtained from the Edmonton Public School Board to run a pilot study with one Biology 30 class in May, 1981, modify the questionnaire if necessary and then administer it in six Biology 30 classes in June, 1981. Six Biology 30 teachers in different schools were contacted through a member of the Department of Secondary Education and all were agreeable to the questionnaires being given to one of their classes in mid-June. Dates were arranged before the final exam so that the students' perceptions of difficulty would not be influenced by final examination questions.

Pilot Study

On May 20th, 1981, the pilot study was carried out. The intents of the researcher were made known to the students and they were exhorted to be as honest as possible. Completion of the questionnaire took approximately fifteen minutes, which was less than anticipated; and following this the researcher was able to engage in discussion with students concerning both the questionnaire format and their perceptions of difficulty. There were no problems with the questionnaire itself; the teacher also saw and approved it, hence it remained unchanged. Of the topics that had been studied by the students, one, namely cellular respiration, emerged as by far the most difficult. This was interesting and not totally unexpected since it was consistent with the views expressed in informal discussion by a number of Biology 30 teachers.

Administration of Student Questionnaire

The questionnaires were administered to six Biology 30 classes in six different high schools within the Edmonton Public School System on June 12th, 15th and 16th, 1981, in all cases before the final exam and in the presence of the researcher, who informed students of her research interests and guaranteed them anonymity. Two of the classes had not completed the curriculum, one had not studied hormones and the other had studied neither hormones nor reproduction. Due to the format of the questionnaire, this did not provide a problem since it was automatically taken into account when difficulty indices were computed as the number of students who described a topic as difficult multiplied by 100 and divided by the number of students who studied it. In most cases there were two or three absentees per class, although in one class there were only fifteen students present out of twenty-eight, which may have been due to the fact that their teacher had announced previously that he would be absent on that day. The total sample was 140 pupils.

Administration of Teacher Questionnaire

A slightly modified questionnaire was sent to all twenty-six Biology 30 teachers in the public school system in late September, 1981 (see Appendix III for teacher questionnaire and covering letters). They were purposely not administered either at the end or the beginning of the school year in order to increase the probability of obtaining a good return rate. Questionnaires were mailed along with a stamped addressed envelope and a covering letter of which there were two varieties, one for those teachers in whose classrooms the researcher had previously administered student questionnaires and the other for those she had not yet

contacted. The researcher's interests were described in the letter and respondents were assured of anonymity. Teachers were requested to classify topics as easy, average, difficult or not taught, for their students, to rank order the five topics that students find most difficult, and to explain the criteria they used in doing so. Approximately one month after they were mailed, twenty had been returned and telephone calls were made to the remaining six, reminding them of the questionnaire. In most cases, due to teachers being in class, messages were left for them. No more were returned so the final number received was 20, or 77%.

Analysis of Questionnaire Data

The data from the questionnaires were analyzed with a number of intents. Firstly, they were used to identify the most difficult topic in the Biology 30 curriculum from the students' perspective. This was achieved by computing difficulty indices and rank ordering topics primarily so that the researcher could proceed to the next and more important phase of the research, namely a situational study in one classroom within the context of the most difficult topic. In addition to this, the questionnaire data were used as sources of additional information regarding subjective perceptions of the difficulty of the various topics in the curriculum, both from the viewpoints of students and teachers. Comparisons were drawn between students' and teachers' perceptions, using χ^2 tests of differences between independent proportions and some indication was gained of the sorts of factors that influence these perceptions.

Qualitative Methodology

Generalization, Validity and the Role of the Researcher as Guiding Concerns

The student questionnaire responses identified cellular respiration as the most difficult topic in the Biology 30 curriculum. This was therefore the context within which the phenomenon of difficulty was further investigated through a situational study in one particular classroom. The aims of this phase of the research were to find out what students mean when they describe something as difficult, to identify contextual factors which influence their perceptions of difficulty and to obtain descriptions of what it is like to experience difficulty in its pedagogic aspect. In order to be able to achieve these intents, decisions were made about the methodology with a number of major issues in mind. The methods grew out of the research questions and were greatly influenced by consideration of concerns such as generalization, validity and the role of the researcher.

Generalization

Due to its situational-interpretive nature and interest in the meanings and significance of events for the participants, this phase of the research did not aim at generalization in the traditional positivistic or empirical-analytic sense with an emphasis on nomological knowledge, but on naturalistic generalization (Stake, 1978; p.6). It aimed instead at beginning to uproot the intersubjective meaning of difficulty and at generalization in the sense expressed by Denton (1974) when he writes:

> "No matter how general the narrative, if the themes or actions can be taken out of the context of that history and appropriated by persons to their lived worlds, the general is translatable to an individual situation." (p.112)

Thus the notion of generalization was understood as whether the reader is able to relate to what is described, remove it from the stated context and interpret it in terms of his own life world. In order to achieve this the researcher hoped to unearth descriptions of difficulty that would make sense to her readers in relation to their own lived experience. In a similar way the notion of a sample which is representative of a larger population is inappropriate to the present research since the interest lay in one particular context, namely the participants of one biology classroom. The descriptions proffered by both students and teacher were thus regarded as examples which hopefully speak in some meaningful way to the notion of difficulty as experienced in everyday life.

Validity

Validity was a major consideration when planning and carrying out the situational study. It is defined by Dawson (1979) as "the adequacy of a description as a representation of a social situation" (p.1), and concerns the issue of whether or not a description is an accurate interpretation of the situation as lived by its participants. Dawson suggests various ways in which this can be addressed in qualitative research, one of which is "the effort to confirm or disconfirm findings by asking participants to react to the researcher's perceptions and "interpretations" (p.4). In a similar way, Psathas (1973) suggests three tests of validity; the first being to ask "the extent to which the findings are faithful to and consistent with the experiences of those who live in that world" (p.12). The second test of validity is whether or not the descriptions would allow the reader to understand and recognize the particular activities under investigation when confronted with them, and finally Psathas suggests that the accounts should allow the reader to become a "player" after having

read "the rules." For the purposes of the present research, major consideration was given to the first test of Psathas and a number of steps were taken when planning the study to increase the likelihood of accurate and consistent descriptions. The latter two tests of Psathas require validation by the reader rather than the participants, thus consideration of them only indirectly affected research methods.

The Role of the Researcher

The role played by the researcher was viewed of utmost importance in a variety of ways and awareness of this affected methodological decisions concerning research procedure. It is evident that in any research, but especially so in the situational-interpretive mode, the researcher influences the situation by her presence and hence affects her descriptions in a number of ways. It is impossible to gauge the exact extent of such an influence on the participants and situation as a whole but every effort had to be taken to attempt to minimize such effects. In a similar way, the background of the researcher in terms of her biographical situation, predominant interests and intents and more nebulous philosophical assumptions about classroom life inevitably affect her interpretations and perceptions of the situation in question. The researcher therefore attempted to be aware of some of her preconceptions and assumptions concerning the phenomenon of difficulty and how it is experienced in the biology classroom.

Overview of Research Activities

A number of different activities were carried out as part of the situational study in order to gain a deeper understanding of the meaning of difficulty for pupils and teacher, and to obtain descriptions of what

it is like to experience difficulty within the context of the Biology 30 curriculum. The researcher assumed the role of participant observer in all six classes on cellular respiration. She sat at the back of the room, taking field notes while the class was recorded. In addition to this, interview was the major method employed to elucidate students' and teacher's perceptions of the classes. The teacher was interviewed daily at a convenient time, as was a group of four students, three female and one male. Another seven students were interviewed individually once during the unit, usually for fifteen to thirty minutes. Journals of classes were kept by a further eight students and given to the researcher at the end of the unit. These pupils were asked to give their subjective perceptions of the classes, for example whether they were easy or difficult, interesting or boring. During the last class period on cellular respiration, every student in the class was asked to describe a difficult experience they had encountered within this context. In order to try and develop an increasing awareness of her own views, the researcher kept a journal for a period of six weeks while she was involved in this phase of the research. This enabled later reflection in a deeper and more meaningful way on some of the major problems and concerns while carrying out the research.

Each of these activities was chosen since the researcher believed that it would contribute to a better understanding of the intersubjective meaning of difficulty and its significance in the life worlds of the participants. A detailed description of each of these activities follows, reflecting the researcher's constant concern with such issues as validity and her role.

Research Activities

Selection of Situation and Entry

A number of teachers were approached to see whether they were interested in participating in the study. One teacher seemed enthusiastic but timetabling proved impossible since the researcher had university commitments in the mornings. Mrs. T. was contacted and sounded receptive so a meeting was set up to discuss the project. This took place on Friday, 10th September, 1981, at the school during one of her free periods. The nature of the research was discussed, including the length of time and the types of activities such as in-class observation and interviews that would be involved. The researcher learned to her disappointment that Mrs. T. only expected to spend one week teaching cellular respiration—less than anticipated. Mrs. T. was most enthusiastic and extremely helpful. She made the decision to help with the research there and then, and offered useful suggestions such as tape recording the classes. A major concern of the discussion was what to inform students regarding the research interests. No final decision was made although at that time it seemed likely that they would be given a very general description, not specifically concerning difficulty. This was later changed on the basis that a more direct approach would probably increase the chances of obtaining relevant descriptions.

On Monday, 21st September, Mrs. T. discussed the situational study with her Biology 30 class and later asked for an indication of how many students would be willing to help either by being interviewed in a group or individually, or by writing a journal. Happily, over half the class volunteered. A week later, on Monday, 28th September, the researcher spoke to the class and described her interest in difficulty and the reason

for studying it within the context of cellular respiration. She identified herself as both a university student and a biology teacher. Later in the week, volunteers were called for, both the researcher and Mrs. T. asking individual students if they would be willing to assist. Twenty out of the thirty-two students volunteered, stating their preference for the type of activity in which they would be involved. On the basis of this, lists were drawn up of students to be interviewed individually and in a group, plus those who were to keep journals throughout the cellular respiration unit. Of the twenty students who offered to assist with the research, fifteen were female, five male, and all except one of those interviewed were female. The participants were by and large the more capable members of the class, as reflected by their academic success on traditional measures of achievement such as unit exams.

Participant Observation

Junker (1960) defines the four stances of the participant observer as: complete participant, participant as observer, observer as participant and complete observer. In all cases the researcher immerses herself to some extent in the lived experience of her subjects, and by virtue of being human cannot escape having to participate in some fashion in the experience and action of those she is observing. In the case of the present situational study, the researcher assumed the role of participant as observer since the participants, namely Mrs. T. and her students, were aware that she was present as a researcher rather than a natural group member.

The importance of developing trusting relationships between the researcher and participants was recognized. Every attempt was made by the researcher to present herself as an open, caring and trustworthy individual

and this was achieved both through her actions and speech. From the inception of the study the participants were assured of the anonymity and confidentiality of the descriptions and opinions expressed to the researcher. Some of the material obtained from students such as that on the irrelevance of much school knowledge suggests that an openness and honesty was achieved with the researcher.

The Presence of the Researcher

The researcher sat at one side at the back of the classroom at a desk, taking field notes and taping the classes. She had been introduced as a university student and a biology teacher; therefore students realized her role as being different from theirs. She tried to be as inconspicuous as possible in order to allow matters to proceed as they would in her absence. However, there were a few occasions when she felt far too conspicuous. One such occasion concerned the tape recording of a class. The tape recorder was placed on the front desk since Mrs. T. did most of the talking. A student had been asked to turn the tape over when the side finished but she had obviously forgotten. Time went on and eventually this necessitated the researcher getting up from her place at the back, walking all the way to the front of the class, turning the tape over and returning to her seat. This incident worried the researcher greatly and she later raised the issue with Mrs. T. Discussion showed that Mrs. T. did not perceive it as a problem, said it had not disturbed her and had spoken of other constant interruptions such as students moving around the room for a variety of reasons, visitors at the door, telephone calls, and so on. It was

interesting to note in this case the difference between the perceptions of the researcher and the teacher, the former feeling that she was a nuisance and a disturbance, the latter being unconcerned.

Throughout the study, the researcher was aware that her presence was influencing the situation. Stoddart (1978) states:

> "The good ethnographer regards his own presence in a domain as potentially tainting of its natural state." (p.3)

Apart from being aware of this influence and attempting to be as unobtrusive as possible, there is little that can be done to discover the precise extent of such reactive effects. One factor which may have helped in this respect is that the researcher was present in the class for approximately one week before the unit on cellular respiration was begun. This was done in order for all involved to get used to her presence, and is referred to by Stoddart (1978) as "disattending: erosion of visibility by time."

Further to the role of the participant as observer, two incidents should be mentioned. On one occasion, a student who sat at the back of the class was eating some chips. He looked over towards the researcher who happened to be glancing over in his direction and their eyes met. The student looked guilty and the researcher quietly told him to ignore her. On reflection it might have been better just to have quickly looked away, but as it was the researcher attempted to let the student know that she would not 'tell' on him. On another occasion, one of the students whose desks were closest to that of the researcher was doing some chemistry homework. This gave the researcher the view that the students were not out to make a good impression on her, and were proceeding as normal.

Field Notes

Taking field notes proved to be problematic in terms of what to look for and record. An entry from the researcher's log which she kept consistently during the situational study reads:

> "I feel incompetent at observing. What should I look for? What do I unconsciously look for? What should I write down?"

Since the tape was recording conversation, the researcher was able to focus on what could be seen and yet she wondered how much bodily movements told her about the students' interpretations and perceptions of the class. Various descriptions were obtained of students yawning, stretching, sitting with pensive looks, resting their faces in their hands and so on but it seemed that in order to go beyond this the researcher had to talk to the students involved. It therefore became evident that since her primary interest was in the meanings students attributed to the various activities and situations within the class, field notes concerned with observable outward behaviours were of limited value.

The Emic Stance of the Researcher

A further problem concerning participant observation was that of the researcher being very close to the situation in terms of her background experience as a biology teacher. The log states:

> "I'm worried that my class observations are almost nonexistent. I need to be more observant and try to suspend my assumptions. It's all so 'everyday' and natural to me that I find it difficult to see what's really going on."

This appears to be one consequence of the researcher's emic stance (Pike, 1967) and various issues arise regarding this. The first has already been mentioned, namely the difficulty of seeing the familiar through 'new lenses,' and has been discussed by such authors as Wolcott

(1975) and Wax and Gearing (1971) who suggest that a beginning researcher should initially perform cross-cultural research. Secondly, there was the problem of becoming so interested in the subject matter being taught that the researcher failed to pay attention to what was going on in the class, and finally, there was the question of how the researcher herself would have taught the unit and whether she agreed with the methods used by Mrs. T. It was recognized that the role of the researcher did not involve evaluation per se but in view of her background she did find herself making value judgments about the worth of a particular approach or activity. Two specific procedures were perceived negatively and the researcher had to guard against showing her opinions on them. Mrs. T. expressed the view that if the research showed that the majority of students were having difficulty with particular aspects of her presentation she would change her teaching style in an attempt to overcome this. However, she never at any point asked for the researcher's views on the teaching methods and procedures used, and the researcher felt strongly that although she inevitably held certain opinions it was not her position to discuss them.

The Objectivity Myth

The question of objectivity or neutrality was constantly of major concern to the researcher, especially before she went into school to carry out the situational study. The notion of the disinterested observer as proposed by Schutz (1970) raises the issue of bias, and relates back to previous discussion on taking field notes and the reactive effects of the researcher. A further incident should help to

illustrate this. Mrs. T. used questioning in her lectures and fairly frequently called on individual students to respond. After class one day a group of boys approached her and said they felt they were being "picked on," both regarding being questioned and other matters. One had recently been moved to the front of the class for chatting too much. It transpired that they felt that another student who chatted more but had not been moved was receiving preferential treatment. Mrs. T. related the story to the researcher and was fairly upset about it. The researcher tended to agree with the students' complaint but obviously could not say so or do anything except sympathize with Mrs. T. It was incidents such as these that put the researcher in an awkward position. This was partly due to Mrs. T.'s openness and strong desire for self-improvement since the researcher felt that she would have appreciated the opportunity to discuss such matters further. Throughout the study, therefore, it seemed that the researcher had the job of, on the one hand, showing that she was human, and yet trying not to influence the situation unduly or to act in any way that might interfere with her perceived role.

With further regard to the subjectivity versus objectivity issue, another log entry states:

> "I'm no longer uptight about my influence on the data. That's obvious and the only way it could be. After all, I decided on the thesis topic, did the readings and so on, so from that point of view I don't see the problem. But then I think a little more and the whole concept of bias raises its ugly head as something bad—it's almost/it is ? an irrational, illogical fear. . . It is a worry though—just comments I make like,'That was a good discussion', or, 'That was an interesting discussion', how much influence do they have in terms of what they think I want to hear? It's also difficult knowing how to guide the discussion without leading it too much."

This reflects the researcher's concern that her personal orientation and preconceptions were seriously affecting the study, and yet she was aware that this was unavoidable since one cannot exist independent of interests and intents. It is precisely these interests and intents that constitute being human and thus continually influence one's actions and perceptions. On the basis of this, objectivity is an impossibility. Denzin (1970) writes thus:

> "It is impossible not to take ethical and value stances in the process of research. When analysts choose to enter one social setting and not another, they have made an implicit value decision that one is better than the other for their purposes."(p.325)

It is evident therefore that throughout the study the researcher was faced with making decisions about how to proceed and inherent within these decisions were statements about herself and how she perceived her research.

Transcriptions and Accounts of Classes

Mrs. T. taught six classes on cellular respiration, the researcher being present at and taping each of these. Every evening the tapes were carefully transcribed so that the researcher had an accurate representation of what had occurred in class on that particular day. This method was time-consuming but most helpful since it enabled the researcher to have a detailed and up-to-date view of activities, statements, questions and so on. In this way it aided in providing a more holistic appreciation of the unit, and in acquainting the researcher more closely with her material. The transcriptions were then used as a basis for writing one- to three-page accounts of each class. These accounts described as closely as possible what took place during class and were returned to Mrs. T. the following day.

The purpose of this procedure was validation by the participant and was achieved by Mrs. T. reading the descriptions, correcting them or commenting wherever necessary and returning them to the researcher. It thus enabled the researcher to compare her perceptions of the situation with those of Mrs. T., confirming or disconfirming her interpretations. The results of the validation technique demonstrated a close compatibility of perceptions since the only corrections made were for clarification on factual matters. An example of this was when the researcher did not know the name of the slide-tape presentation and left a blank space which Mrs. T. filled in. Similarly, Mrs. T. had clarified whether a fly or a bee was used in a particular experiment shown in an introductory film. The only other change suggested throughout the six accounts was the substitution of the term"narrator" for"announcer"with reference to a slide-tape presentation. It is evident, therefore, that these were all minor changes and that the interpretations of the researcher matched with those of the teacher. With reference to the likelihood of modifying or correcting such accounts, Stake and Easley (1978) state: "Contrary to popular expectations, people seldom exercise the options other than occasionally a request for correction of fact." (p. 34).

Interviews

Intents and Interests

Six daily interviews were carried out separately with Mrs. T. and a group of four students throughout the unit on cellular respiration, and a further seven students were interviewed individually on one occasion. The purpose of all the interviews was to provide the

researcher with the opportunity to engage in dialogue with the participants and thereby come to a deeper understanding of their perceptions of difficulty within the unit. The interviews were carried out either during the lunch break or spare periods in Room 117, which was close to the biology classrooms. It had been set aside as a workroom for the biology teachers and was therefore unoccupied at most times during the day.

All the interviews lasted between fifteen and thirty minutes, were taped with the interviewees' permission and could be described as semi-structured. Generally, the daily interviews both with the group and Mrs. T. were focussed around discussion of particular class activities and how these were perceived and interpreted in terms of such issues as ease, difficulty, interest or disinterest. However, in addition to starting from the concrete activities the discussions led in a number of different directions and varied substantially day to day. Interviews with individual students tended to be more general in terms of their overall perceptions of the unit. For both types of interview the researcher generally had a number of questions written down which formed the basis of the interview, although this was more frequent and consistent with regard to the individual interviews, most of which followed a fairly similar format (See Appendix IV for Questions for Individual Student Interviews). However, all interviews were open-ended and flexible; thus enabling the discussion to develop naturally while simultaneously allowing the researcher to direct the participants' thoughts towards certain areas of interest.

Mrs. T. was questioned on the various activities and materials in terms of her intents for their use at that particular point in time.

The researcher also encouraged her to reflect on whether she felt that students were experiencing difficulty and how she came to that view. Later interviews involved some discussion of the nature of difficulty (See Appendix VC).

Arranging and effecting the interviews required a certain amount of flexibility both on the part of the researcher, Mrs. T., and the students, since there were often last minute changes in plans. All except one of the scheduled interviews took place and this was due to the particular student's absence from school on the last day of the unit on cellular respiration. Another change was that two students were interviewed together instead of separately, because one of them had to attend an unexpected meeting at the scheduled interview time (See Appendix VA).

Group Interviews

The group of four students was interviewed on six occasions, the last of which was after the unit exam on cellular respiration. Initially all students attended the discussions but after a while it was not uncommon to have only two or three of them present on any particular day. This was unfortunate but the researcher did not feel that she could reprimand them since the interviews were involving a demand on their time in the lunch hours, and she was therefore most grateful for their cooperation. About half of the absences were accidental due to forgetting the meetings and other reasons included a dentist appointment and a student finishing homework for an afternoon class. It was noticeable within the group that one student tended to dominate the discussion at times, hence the one time he was not present other quieter members were given more of a chance to express their views.

Generally, the researcher was pleased with the majority of interviews. It appeared that students felt free to express their views and concerns and did not hesitate to speak their minds, for example when they described certain aspects or activities of the unit as difficult, boring or irrelevant. The group interviews were especially pleasing since students were very spontaneous, and the interaction between members was high, one student making a statement, followed by others spontaneously agreeing or disagreeing. Such patterns enabled the researcher to discover whether views were subjectively or intersubjectively held. An initial problem with the group interviews was the difficulty encountered by the researcher in differentiating between the voices of two of the girls when transcribing; however, this was overcome by the second interview.

The Quality of Interviews

The quality of the interviews varied according to the questions asked by the interviewer and the articulation of the interviewees. There were noticeable differences between some of the students in terms of their ability to express their ideas clearly and succinctly. For example, one particular student had a tendency to contradict herself, as illustrated by the following:

Int: "Is it fairly easy to understand?"
St: "Yep; sometimes it confuses you."

Another factor which influenced the quality of particular interviews was the amount of time available. For example, one of the interviews with Mrs. T. was severely constrained in this way due to having to fit it into a certain number of minutes in the lunch break, and the sense of being rushed which resulted from knowing this. Another

unfortunate occurrence during an interview with Mrs. T. was a telephone call for her in the office, which necessitated stopping the interview with the intent of continuing later. As it happened, it was not completed, mainly due to the researcher's realization that Mrs. T. was extremely busy later that day and had a number of things on her mind.

Transcriptions and Accounts of Interviews

All interviews were taped and transcribed by the researcher that evening. From the transcriptions, one- to three-page accounts were written of the interviews and were returned to the participants the following day (See Appendix V for examples of transcriptions and accounts of interviews). In a similar fashion to the accounts of the classes themselves, the intent of these was validation. Therefore the students and teacher were asked to carefully read through the accounts, comment on their accuracy, make changes where necessary and return them to the researcher. In the case of the group interviews, copies were made and one given to each member. In this way the researcher was able to check whether her perceptions and interpretations of what participants had said matched with their own; or in the words of Psathas (1973) she asked "the extent to which the findings are faithful to and consistent with the experiences of those who live in that world." (p.12)

Very few changes were made to the accounts by the participants. In the case of the group interviews, the only corrections required concerned which student had made a particular statement, the major cause of this being the researcher's initial difficulty in distinguishing between the voices of two girls in the group. While reading the account of Group Interview 3, which mainly focussed on the irrelevance

of some high school courses, student number 3 commented, "Oh boy, did I really say that?" regarding a metaphor he had used to illustrate his viewpoint. He had compared being taught certain subjects to "teaching a plough horse to fly an aeroplane even though you know he's never going to fly an aeroplane. He's going to spend the rest of his life pulling a plough."

The accounts of individual interviews required no modification. They were all read by the students involved and returned to the researcher with comments such as, "Yes, that's what happened" or "As far as I remember that's an accurate account of what we discussed." In a similar way to the accounts of the classes, most of the few changes made by Mrs. T. with regard to her interviews were clarifications or corrections of factual matters. For example, there had been discussion in Teacher Interview 1 on the use of the textbook, Biology, by J. W. Kimball in the Biology 30 program. Mrs. T. had described it as the most often used text and the researcher, on writing up the account, was unsure of the population in question. Three alternatives were provided in the account and Mrs. T. checked the most appropriate, namely the Edmonton Public School system.

In a number of cases the researcher had difficulty finding the correct word to express or describe something so she jotted "clumsy" in the margin and Mrs. T. would offer a suggestion. For example, in trying to draw attention to the difference between questions directed at specific individuals and those directed at the class in general, the researcher used the term "undirected" which Mrs. T. changed to "class-directed." Similarly, with regard to a student who was resentful of being told to get on with his work, "teacher pressure" was

suggested as an alternative phrase to "direction to work." Part of the account of Teacher Interview 5 reads: "(Mrs. T.) suggested that if the present class of Biology 30 students achieved a 60% average this would be good enough." Mrs. T. underlined "would be good enough" and inserted in the margin, "This is not to say that I would not like to see a higher average." (See Appendix V for transcription and account of Teacher Interview 5).

It is evident, therefore, that very few changes were made in the accounts written by the researcher, thus suggesting that her interpretations of the interviews were consistent with those of the teacher and students who live in that world. One reason for this may be that the accounts were very "close" to the transcriptions since the researcher tried to avoid making any unjustifiable inferences by ensuring that she could support any statements she made with evidence from what had been said by the participants. It was reassuring to discover in this way that both students, teacher and researcher were "seeing" the same things.

Written Descriptions

Student Journals

Eight students offered to keep journals of the classes on cellular respiration, and it was hoped that these would give them an opportunity to express their subjective views of class activities, with particular emphasis on whether or not they were difficult and what it was like to encounter difficulty in this context. Unfortunately, although most students did make an entry every day, some of the journals amounted to little more than a brief report or account of what happened in class; for example, "Saw slide-tape presentation of cellular respira-

tion" or "Questions asked about specific parts of the cellular respiration unit." Others were of more value since they expressed students' interpretations and views of the various activities. For example, there were comments such as, "It was easy to understand," "This part is confusing" and "The test was impossible." By and large, however, this aspect of the research was disappointing, and this could be attributed to two factors. Firstly, there may have been inadequate direction given to the students involved in terms of the researcher's expectations. Although they were told to express their personal feelings and subjective interpretations of classroom activities, this may not have been sufficiently emphasized. They were not given an example, nor did the researcher check with them adequately throughout the unit to see how the journals were progressing. One student was asked about this and replied to the effect that "It is coming along okay." Secondly, it seems likely that students are rarely asked for this type of description within the school context, perhaps especially so in science. They might therefore not have fully understood that the researcher desired descriptions of their feelings and emotions when experiencing difficulty rather than a list of content or activities that they found difficult. This conflict between the "What is difficult?" and the existential "What is it like to experience difficulty?" was evident, not only with regard to the students but also to Mrs. T. who appeared to have some trouble distinguishing the two.

Student Descriptions

At the end of the unit on cellular respiration all students in the class were asked to describe a difficult experience they had had

during the unit. An example was given of trying to understand the textbook and the researcher stressed her interest in what the experience of difficulty was like for students and how they reacted to it. Unfortunately, the responses were similar to those in the journals. Most descriptions referred to particular content such as the various chemical reactions involved in cellular respiration, but did not get beyond that to reflect on the experience itself. The material thus obtained was useful in identifying contextual factors that appeared to influence student perceptions of difficulty but it was of limited value in gaining descriptions of what it is like to experience difficulty in its pedagogic aspect, and hence to disclose the meaning of difficulty.

Researcher Journal

The researcher kept a daily journal of her involvement in the project over approximately six weeks. Its aim was to provide the opportunity to express more personal subjective interpretations and feelings of how the research was progressing and to be able to reflect on this at a later date. It helped to pinpoint some of the major research concerns and led the researcher to a deeper awareness of some of her preconceptions regarding the experience of difficulty. The journal was an expression of both the hopes and fears of the researcher as she moved through the situational study. It totalled twenty pages, much of which has been of great value, both at the time and later in writing the present chapter.

CHAPTER III

ANALYSIS OF QUANTITATIVE DATA

Data from the student and teacher questionnaires were analyzed in a number of ways. The first section of the questionnaire requested subjects to rate each topic as easy, average, difficult or not taught, and responses from this were used to compute difficulty indices for both students and teachers. These were then compared in order to investigate how the perceptions of the two populations matched. Another question involved the rank ordering of the five most difficult topics in the Biology 30 curriculum and these data were used to compute the percentages of respondents who listed each particular topic as the most difficult. Comparisons were drawn between the students and teachers, the topics were rank-ordered and a Spearman rank order correlation coefficient was computed. The final question of the questionnaire asked respondents to describe the criteria they used in judging a topic as difficult. Answers were read by the researcher and analyzed for common themes. The themes illustrated some structures of reasoning used by respondents to describe contextual factors which influenced their subjective perceptions of difficulty.

Difficulty Indices of Students

Difficulty indices were computed for each of the fourteen topics using the following formula:

$$\text{Difficulty index} = \frac{\text{number of students who described topic as difficult}}{\text{number of students who studied topic}} \times 100$$

Figure II shows the difficulty indices of Biology 30 students for the topics of:

1. Chemistry of cells and reactions
2. Physical properties and processes of cells
3. Transport, translocation and absorption in plants
4. Photosynthesis
5. Heterotrophic nutrition
6. Circulatory system
7. Blood: composition and functions
8. Gas exchange
9. Cellular respiration
10. Energy utilization
11. Excretion by the kidney
12. Hormonal control
13. Nervous control
14. Human reproduction

Indices ranged from 4.9 to 67.1. The difficulty index for cellular respiration was 67.1 and this was followed by hormonal control (36.6), nervous control (35.8), photosynthesis (35.7) and energy utilization (33.3). Students identified human reproduction as the easiest topic.

The difficulty indices of the various topics were compared by sex, using χ^2 tests of significance of differences between proportions of independent samples. It is interesting to note that in eleven out of fourteen cases the difficulty index was higher for girls than for boys. In general, therefore, it appeared that girls perceive topics in the Biology 30 curriculum as more difficult than boys, or at least the way in which they answered the questionnaire reflected a differing perception or meaning of difficulty. In three out of the eleven cases where the index was higher for girls, the difference was significant at the .05 level. Table IV illustrates these differences.

FIGURE II

Difficulty Indices of Students for Biology 30 Topics

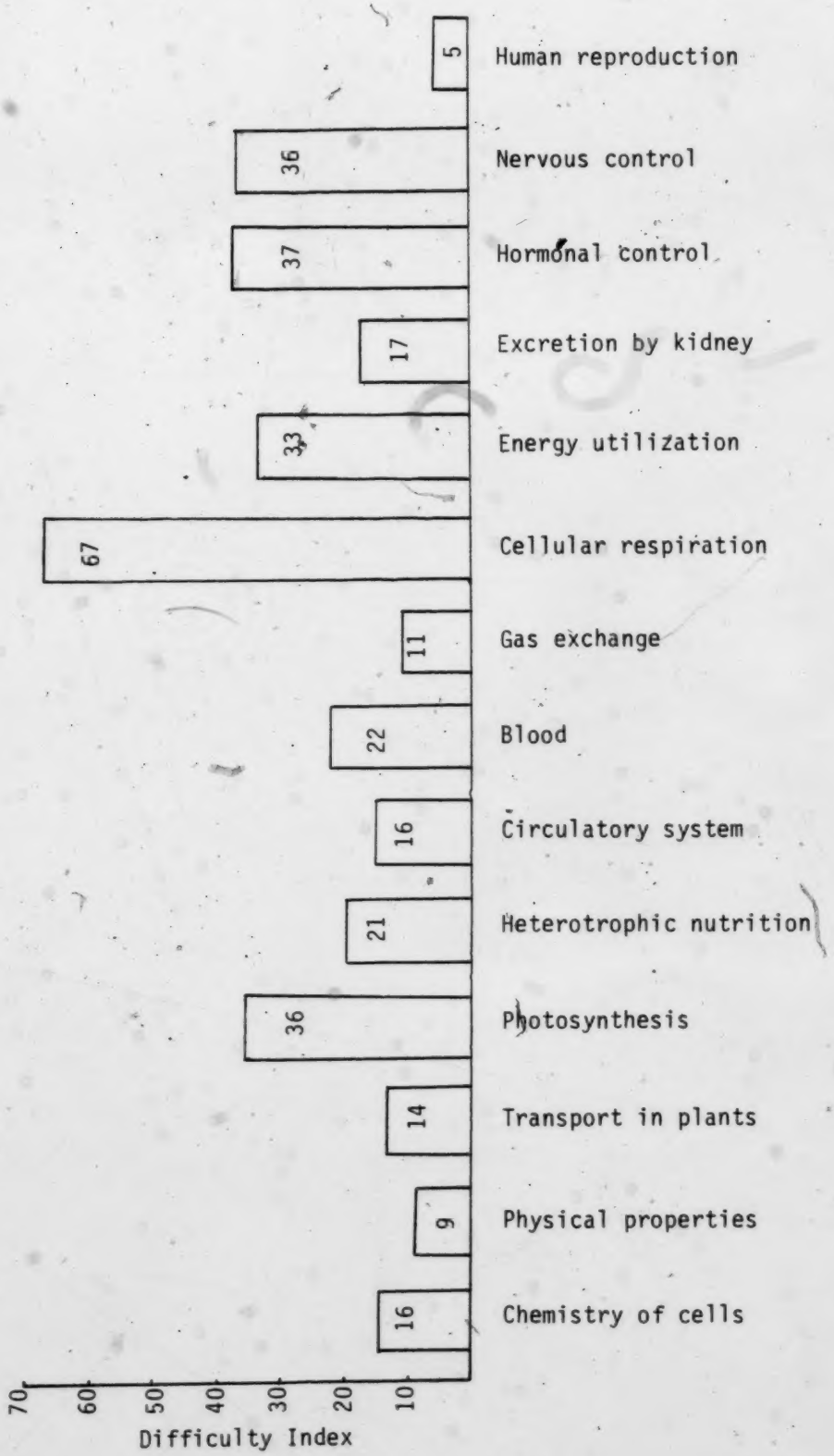


TABLE IV

Significance of Differences Between Difficulty Indices of Boys and Girls for Topics of Biology 30 Curriculum

Topic	Difficulty Indices			χ^2	df	p
	Boys & Girls	Girls	Boys			
Blood: composition and functions	22.1	30.7	12.3	6.81	1	$.001<p<.01$
Energy utilization	33.3	41.7	23.8	4.82	1	$.02<p<.05$
Nervous control	35.8	47.9	21.9	10.09	1	$.001<p<.01$

Rank Ordering of Topics by Students

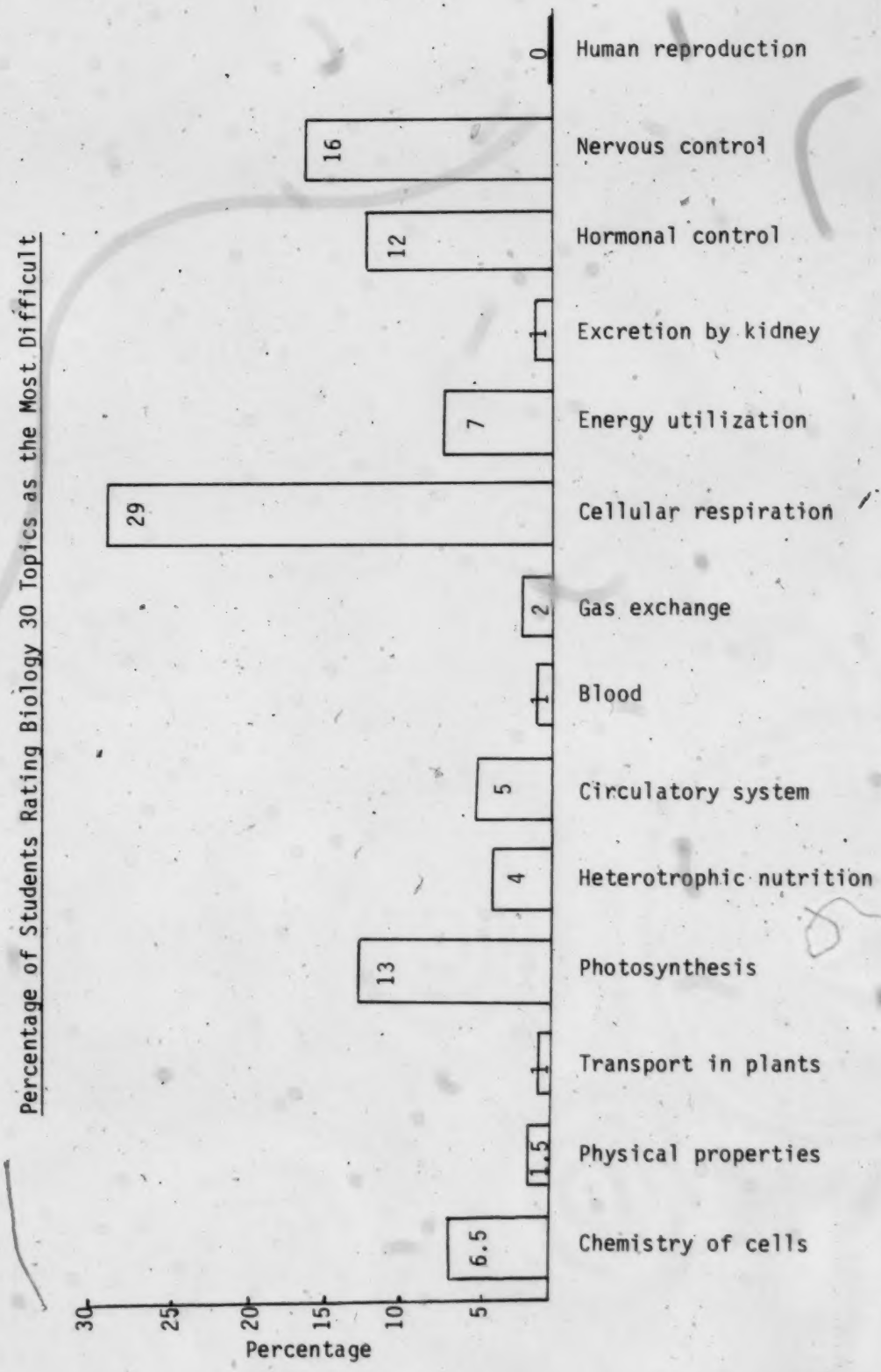
The percentage of students who rated a particular topic as the most difficult of all fourteen is shown in Figure III. Again, cellular respiration was identified as the most difficult. 28.8% of the sample ranked it as number one in terms of difficulty, whereas the next highest values were 15.8% for nervous control, 14.3% for hormonal control and 12.9% for photosynthesis. All other figures were below 10%, the lowest being 0 for human reproduction.

Identification of Most Difficult Topic

The results from these two analyses show quite definitely that cellular respiration is perceived by students to be the most difficult topic in the Biology 30 curriculum, followed by hormonal control, nervous control, photosynthesis and energy utilization, although the order of

FIGURE III

Percentage of Students Rating Biology 30 Topics as the Most Difficult



these varies. 4.3% of the 140 students rated cellular respiration as easy, 28.6% as average and 67.1% as difficult. Regarding the most difficult of all fourteen topics, 28.8% rated it in this way, 23.7% described it as the 2nd most difficult and 14.4% as 3rd most difficult. Thus, 66.9% of all students ranked it as one of the three most difficult units in the curriculum. A further 10.75% ranked it as 4th or 5th, and the remaining 23% did not classify it in the top five.

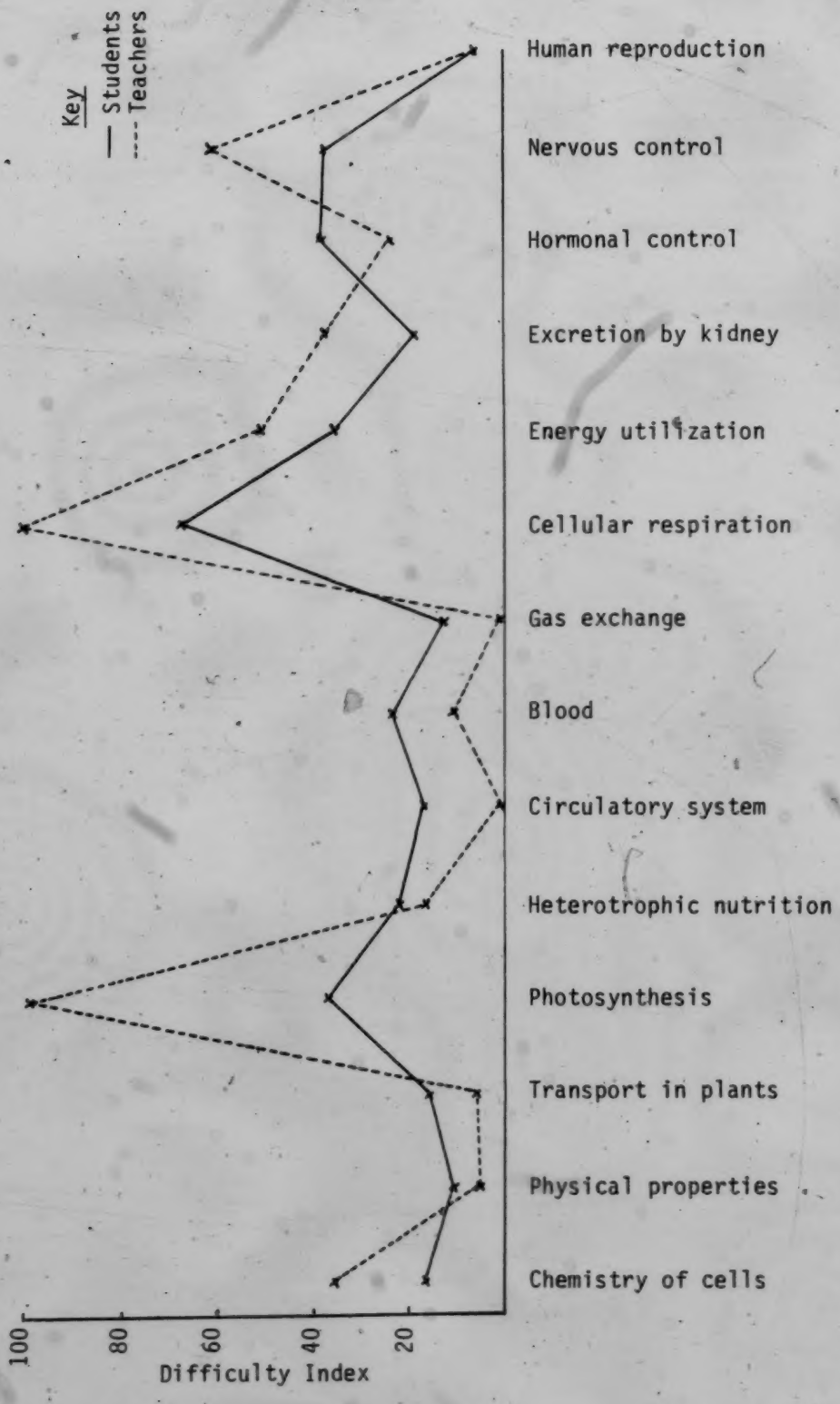
Comparison of Difficulty Indices of Topics by Students and Teachers

Figure IV compares the difficulty indices of the various topics according to both students and teachers. It has been drawn as a frequency polygon for convenience and ease of interpretation although it is realized that the topics are discrete. It is interesting to note that the teachers' difficulty indices for both cellular respiration and photosynthesis were 100. Thus, all of the Biology 30 teachers perceived these topics as difficult for students. Nervous control was rated difficult by the next greatest number of teachers, and had an index of 60, and this was followed by energy utilization, excretion and chemistry of cells. No teachers perceived the circulatory system or gas exchange as problematic; hence the range of difficulty indices was 0 to 100.

Out of fourteen topics, a larger percentage of teachers than students rated six of these as difficult whereas it was the reverse for the remaining eight. The six topics which teachers generally felt to be more difficult than students were: chemistry of cells, photosynthesis, cellular respiration, nervous control, energy utilization and excretion. When χ^2 tests of differences in independent proportions were performed on

FIGURE IV

Difficulty Indices of Students and Teachers for Biology 30 Topics



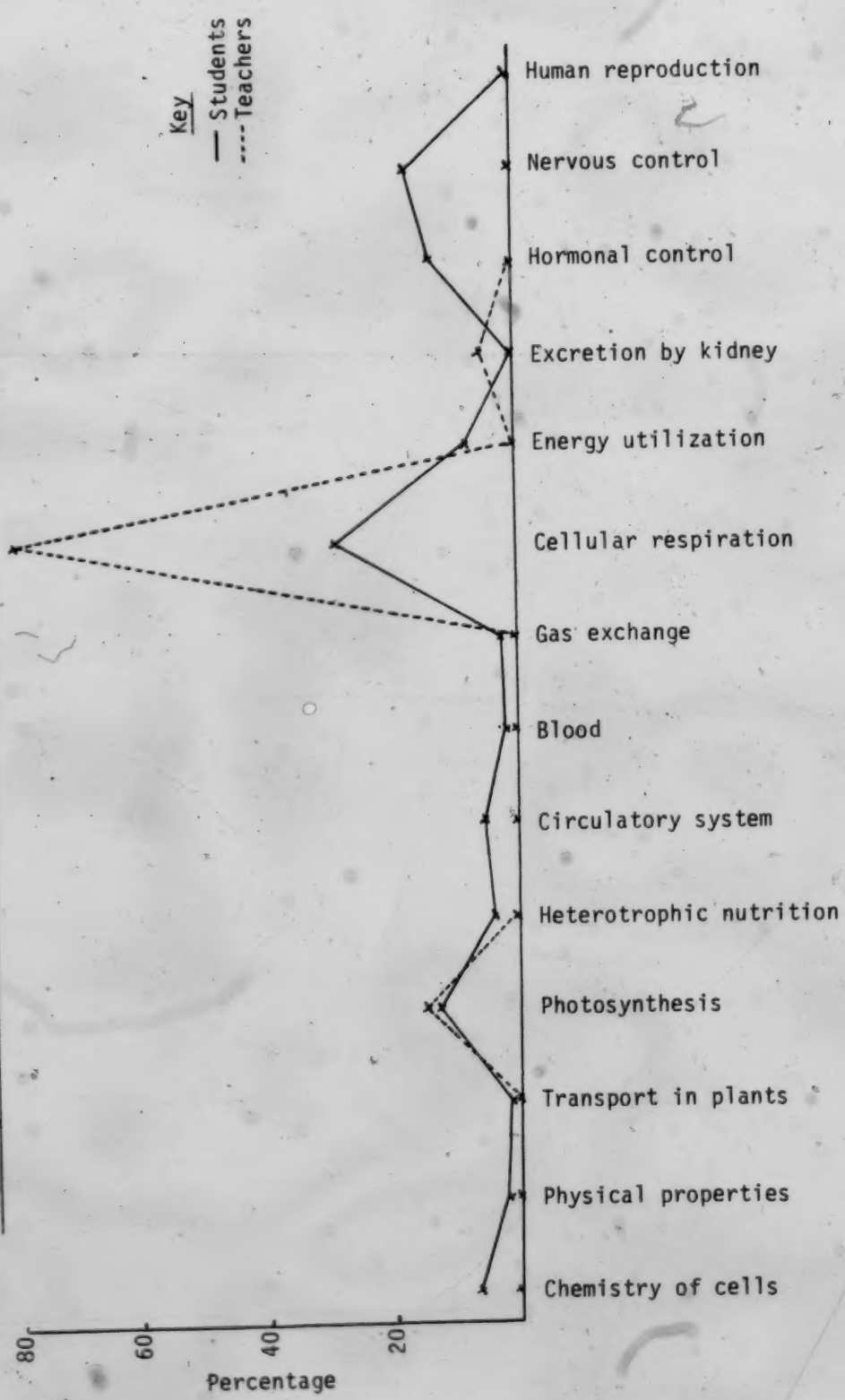
these figures in order to compare student and teacher perceptions of difficulty, differences significant at the .05 level were found regarding the chemistry of cells, photosynthesis, cellular respiration and nervous control. Although the remaining eight topics were rated more difficult by the students than the teachers, none of these were significant. It is evident, therefore, that, in general, teachers rated topics more difficult than the students did. This is supported by the observation that the mean number of topics rated as difficult by students was 3.29 whereas for teachers this figure was 4.4.

Comparison of Rank Ordering of Topics by Students and Teachers

Figure V compares the percentages of students and teachers who described each topic as the most difficult of all. As stated above, the percentages of students ranged from 28.8 to 0, depending on the topic, there being only one topic that no one in the sample described as the most difficult. In contrast to this, the teachers were divided among only three topics, cellular respiration, photosynthesis and hormonal control. Figures for these were respectively 80%, 15% and 5%. χ^2 tests of differences in independent proportions revealed that the difference regarding cellular respiration, namely 80% compared with 29% was significant at the .05 level. It is interesting to note, in this context, how close the teachers' perceptions were to one another whereas the students displayed a greater variety of responses, although the results of both concurred with cellular respiration in the number one position. It is clear from this set of data that although all of the teachers described both cellular

FIGURE V

Percentages of Students and Teachers Rating Biology 30 Topics as the Most Difficult



respiration and photosynthesis as difficult (See Figure IV), most, or 4 out of 5, felt that cellular respiration was the more problematic of the two.

Table V shows the rank orders of the perceived difficulty of topics in the Biology 30 curriculum as assessed by both students and teachers. These data were obtained from the difficulty indices, and illustrate a fairly close relationship between students' and teachers' perceptions. The Spearman rank order correlation coefficient for these figures was .802 which is significant at the .05 level, indicating a generally high correlation and degree of agreement between students' and teachers' views concerning the difficulty of topics in the curriculum.

Factors Affecting Perceptions of Difficulty

Students and teachers were also asked to describe some of the criteria that influenced their decision to rate a topic of the Biology 30 curriculum as difficult. A number of themes emerged from this, some of which are interrelated. Table VI gives some indication of the criteria used by both students and teachers and the percentage of respondents who referred to them. Criteria included: complexity and detail, memorization, chemistry, terminology, new material, lack of interest, relevance and insufficient time spent on the material. The most frequent factors which respondents mentioned as influencing their perceptions of difficulty were complexity and detail, chemistry and memorization.

Complexity, Detail and Memorization

Complexity and amount of detail were mentioned by 52% of students and 39% of teachers. If a topic involves a large volume of material

TABLE V

Rank Order of Difficult Topics in Biology 30 Curriculum

Students	Teachers
Cellular Respiration	Cellular Respiration
Hormonal Control	Photosynthesis
Nervous Control	Nervous Control
Photosynthesis	Energy Utilization
Energy Utilization	Excretion by Kidney
Blood: Composition and Functions	Chemistry of Cells
Heterotrophic Nutrition	Hormonal Control
Excretion by Kidney	Heterotrophic Nutrition
Circulatory System	Blood: Composition and Functions
Chemistry of Cells	Transport in Plants
Transport in Plants	Physical Properties of Cells
Gas Exchange	Reproduction
Physical Properties of Cells	Circulatory System
Reproduction	Gas Exchange

TABLE VI

Percentage of Questionnaire Respondents referring to Particular Criteria for Judging Biology 30 Topics as Difficult

	Students	Teachers
Complexity and detail	52.5	38.9
Memorization	27.7	11.1
Chemistry	24.8	55.5
Terminology	10.2	5.5
New material	10.2	5.5
Lack of interest	14.6	11.1
Relevance	7.3	5.5
Amount time required to understand	16.1	16.7
Abstract		22.2
Insufficient time on topic	16.8	
Test results	9.5	33.3
Poor teaching	5.1	
Student comments and responses		38.9
Student study habits		11.1

including many small details, it is likely to be described as difficult. Students said:

> "The more of the specific details, the more difficult was the unit."
> "The most difficult topics were those that involved many details, complicated steps to memorize;"

and adjectives such as involved, detailed, specific, complex, long and complicated were used to describe difficult topics. Teachers used a similar frame of reference when they stated:

> "The amount of technical detail and ideas account for the difficulty."
> "A topic is difficult where the material is too complicated or requires too much depth to fully understand."
> "Complex topics provide a challenge to the best of students."

Cellular respiration does involve much detail in the form of the various chemical cycles such as glycolysis, citric acid cycle and the cytochrome enzyme system within which there are a multitude of different chemical reactions concerning the transfer of electrons.

Also related to the notion of complexity, 27% of students and 11% of teachers mentioned the influence of memorization on their perceptions; for example:

> "More material to memorize makes it hard."
> "A lot of memory work"
> "Remembering detailed sequences."

Terminology

Terminology was another related factor. Students stated:

> "Some topics have endless supplies of big words."
> "The terms used are difficult and confusing."
> "Involved a lot of technical terms."

Cellular respiration is a prime example of this phenomenon since students have to become familiar with a large number of terms such as glycolysis, phosphorylation, fermentation, aerobic and anaerobic respiration, citric

acid cycle, adenosine diphosphate, adenosine triphosphate and cytochrome enzyme system plus the names of the particular chemicals involved, such as: phosphoglyceraldehyde (PGAL), pyruvic acid, α-ketoglutaric acid and cytochrome oxidase. An added complication is that some of the processes are known by more than one name, for example, Krebs' cycle is synonymous with citric acid cycle, cytochrome enzyme system, with hydrogen transfer system. Therefore, in addition to learning the various names for the different processes, students need to become familiar with the different names for the same process.

Chemistry

Another factor mentioned as a significant influence on students' and teachers' perceptions of difficulty in the Biology 30 curriculum was the involvement of chemistry. 25% of students and 55% of teachers described it as a significant problem. Students wrote:

> "You have to have a strong chemistry background in order to pass this course."
> "I thought these topics were difficult because of my lack of knowledge in chemistry."
> "Chemistry does not belong in a Biology 30 course."

Teachers agreed when they reasoned:

> "Students have an inadequate understanding of chemistry to understand the principles of biochemistry."
> "The more chemistry and chemical reactions involved, the more difficult the topic."
> "Because chemistry is not a prerequisite for Biology 30, the difficulty arises when an explanation requiring the use of chemistry is used. As a consequence, the amount of time and effort required to teach the above ranked topics increase with increasing amount of chemistry used."

Again it is obvious that cellular respiration involves much chemistry in the form of reactions, symbols and formulae. Therefore, this may be one of the factors contributing to its being perceived as very difficult.

Other topics which the use of chemistry apply to are photosynthesis and certain aspects of cell biology.

Introduction of New Material

The introduction of a large amount of new material was also given as a criterion by which the difficulty of a topic was assessed. Students expressed the following views:

> "They're difficult because each was a completely new subject."
> "The amount of knowledge that the student already has on any given topic is bound to influence his grasp of the subject. The areas I had some difficulty with were areas that I was not as familiar with as the other areas of study."
> "They were sections which I knew almost nothing about before starting the unit. In two weeks I had to learn all the general background and new detailed information about a topic which I had had absolutely no understanding of before."

Teachers appeared to support such opinions with statements like:

> "The material is completely new to them and therefore the concepts are sometimes very difficult to understand."

Relevance and Interest

The notion of relevance was discussed as a criterion by which to judge the difficulty of topics in the Biology 30 curriculum. Both students and teachers appeared to relate the irrelevance or impracticality of a topic to its difficulty when they stated:

> "It's hard to concentrate on topics which seem so totally irrelevant to today's society. One feels you will never find it useful material anyways unless you are a scientist."
> "I was unable to utilize them in a practical sense."
> "I felt that the total reason for teaching said subject totally and completely escaped me."

Student interest or lack of interest in a topic was another structure of reasoning illustrated by comments by both students and teachers, when they said:

"Generally, the topics of least interest to me were difficult. I found great difficulty in relating to certain uninteresting topics."
"This topic I didn't find too terribly interesting, therefore making it difficult for myself."
"The ones I ranked as difficult, I was not as interested in them."

Similarly, teachers wrote:

"Perhaps in my ratings I associated the problem of maintaining interest with the level of concept difficulty. Students find difficult what they are not particularly interested in."
"Not exciting."

These remarks point to some sort of relationship between difficulty and interest, and support findings from the study by Kelly and Monger (1974).

Time

Students related difficulty to the amount of time and effort required to understand the subject matter. They wrote:

"The topics I had to really think about and read carefully to understand were difficult."
"I had to read it a lot of times before understanding it."
"I seemed not to grasp the ideas very clearly or easily."

Similarly, difficulty was reflected in the amount of time needed to study for the test, and comments illustrating this included:

"Difficulty is inversely proportional to the amount of study done."
"The difficulty was decided by how much time was required to adequately prepare for a test on the subject."
"The topics which I felt were difficult were the ones which I had to spend the most time studying for."

In a number of cases, students felt that insufficient time was devoted to a particular topic and hence it was perceived as difficult. With regard to this phenomenon students stated:

"There was a lot of material to be learned in a short time."
"These topics were rated as difficult because there wasn't enough time. We were rushed into it."
"I rated these topics as difficult for such factors as teaching too much stuff in too little time—cramming, thus not covering them in depth and getting a thorough understanding."
"Teacher moved along too fast."

From the teachers' perspective, the relationship between difficulty and the amount of time required to teach a topic was illustrated by such remarks as:

> "I am equating student difficulty with the amount of time required by the teacher to cover the topic."
> "The amount of time and effort required to teach the above-ranked topics increase with increasing amount of chemistry used."

Test Results

Test results were mentioned by 33.3% of teachers and 9.5% of students as evidence that a particular topic was difficult. It appeared that they used these as an indication of difficulty, for example:

> "The major factor that influenced my decision was my exam marks for each unit. The ones I ranked as the most difficult were the ones I did most poorly on."

Other students discussed "bad marks received in that area" and "how well I did on the tests of those sections." Teachers also made reference to test marks as well as to comments and responses by students both in and out of class which indicated that they were experiencing difficulty. Teachers thus obtain evidence of students' perceptions of difficulty both from subjective and objective information. It is interesting to reflect in this context on the difference between subjective perceptions of difficulty as experienced and objective measurements of difficulty for example on a test. In the case of a test, the difficulty is measured or quantified by an instrument external to the knower, whereas alternatively, difficulty can be perceived as a subjective and existential encounter which is felt and experienced by individuals within their life worlds.

Summary

Questionnaire responses were useful to the researcher in a number of ways. They provided information on both students' and teachers' perceptions of difficulty of topics within the Biology 30 curriculum so that the most difficult topic could be identified for further in-depth research through a situational study in one classroom. In addition to the isolation of this particular topic, information was obtained concerning the other topics in the curriculum. Results of the computation of difficulty indices and the percentages of respondents who ranked each topic as the most difficult of all showed cellular respiration to be in the number one position, followed by hormonal control, nervous control, photosynthesis and energy utilization. On comparing difficulty indices of students and teachers it was evident that generally the perceptions of the two groups were fairly similar as shown by a Spearman rank order correlation coefficient of .802 which was significant at the .05 level.

Written comments of respondents indicated a variety of criteria which were used to judge a topic as difficult. The most frequent references were to complexity, amount of detail, memorization, chemistry, terminology, the introduction of new material and lack of interest. Both students and teachers used such structures of reasoning to describe some contextual factors which influenced their subjective perceptions of difficulty. Time, test results and student responses and informal comments were also given as criteria which respondents used to assess the difficulty of the fourteen topics in the Biology 30 curriculum. Some of the remarks suggested that there may be a fundamental difference between difficulty as subjectively experienced and difficulty as objectively measured.

Questionnaire data enabled cellular respiration to be identified as the most difficult topic in the Biology 30 curriculum from the viewpoints of both students and teachers. This was therefore the context within which a situational study was carried out in one classroom to try and reveal the intersubjective meaning of difficulty.

CHAPTER IV

ANALYSIS OF QUALITATIVE DATA

This chapter examines the notion of difficulty at three different and ever-deepening levels, and includes both descriptions obtained during the situational study and the researcher's interpretations of these descriptions in an attempt to move beyond the concrete to a deeper understanding of the meaning of difficulty.

Initially a description is given of the biology class used as the context for the situational study. The three types of teacher-directed activities which occurred in this situation are investigated in the light of students' and teacher's comments; the main focus being the relationship between the various activities and perceptions of difficulty. Student descriptions are used to illustrate attitudes toward the classroom activities and the material that caused them the greatest problems. The following section which is still part of the first level of analysis describes factors which were mentioned as influencing subjective perceptions of difficulty within the context of cellular respiration. These emerged during interviews with the participants and have been arranged under various themes such as complexity, detail, memorization and chemistry. Again the majority of the material comprises direct quotations from students.

The second level of analysis involves a closer examination of descriptions of difficult experiences, and aims to move toward revealing the intersubjective and usually taken-for-granted meaning of difficulty.

A number of commonly used expressions are investigated for what they disclose about the meaning of difficulty as experienced within the Biology 30 classroom. Themes such as being confused, clearing up, figuring out and being lost are considered in light of what they tell about the experience itself. Following this, a closer look is taken at descriptions that illustrate the sense of frustration experienced when confronted with difficulty. The notions of trying, losing hope and turning off emerge as important in this respect.

The third and final level of analysis goes beyond the previous two in the sense of attempting to get beneath the ground structures to the deep structures of difficulty. It looks at some of the assumptions underlying the predominant curriculum concern to eradicate difficulty and asks whether this is truly desirable. By reflecting on the nature of difficulty the researcher asks whether it is one of life's ways of challenging us to be virtuous and to grow beyond ourselves. It is suggested that difficulty be perceived as a particular mode of being in the world and one which is essential to the living of life as we know it.

Participants' Perceptions of Difficulty

Description of Situation

Mrs. T. spent six classes from Tuesday, 6th October, to Wednesday, 14th October, teaching cellular respiration to the Biology 30 class. On each day except Thursday, the class ran from 8:00 - 9:04 a.m., while on Thursday there was a double period from 8:00 - 10:18 a.m., with a ten-minute break in the middle. On Thursday, the first period comprised a review of photosynthesis.

Room 120, where Mrs. T. taught her Biology 30 class, is a large, well-lit room with curtained windows at the back. Students' desks are arranged neatly in rows and there is a teacher's desk and chair at the front of the room. Also present in the room are: chalkboards, a bulletin board, cupboards with biological specimens, overhead projector, filing cabinets, book cases with biology texts, biological models of various mammalian organs, charts and trolleys with grow lights (See Figure VI). All the students in the class were in Grade 12; most wore jeans and sweat shirts or sweaters and sneakers. Of 32 students, 21 were female, 11 male.

A variety of activities took place during the unit on cellular respiration, including students working individually on objectives from the textbook, a film, a slide-tape presentation in two parts, lectures and a questioning session. Students were given a five page 'unit' which included a brief introduction to cellular respiration, a list of fourteen student objectives, a list of required learning activities and three appendices outlining the chemical reactions involved in glycolysis, the citric acid cycle and the hydrogen transfer system, respectively (See Appendix VI). The materials used by Mrs. T. and the students were: film, slide tape, overhead projector, transparencies, textbook, chalkboard and the 'unit'.

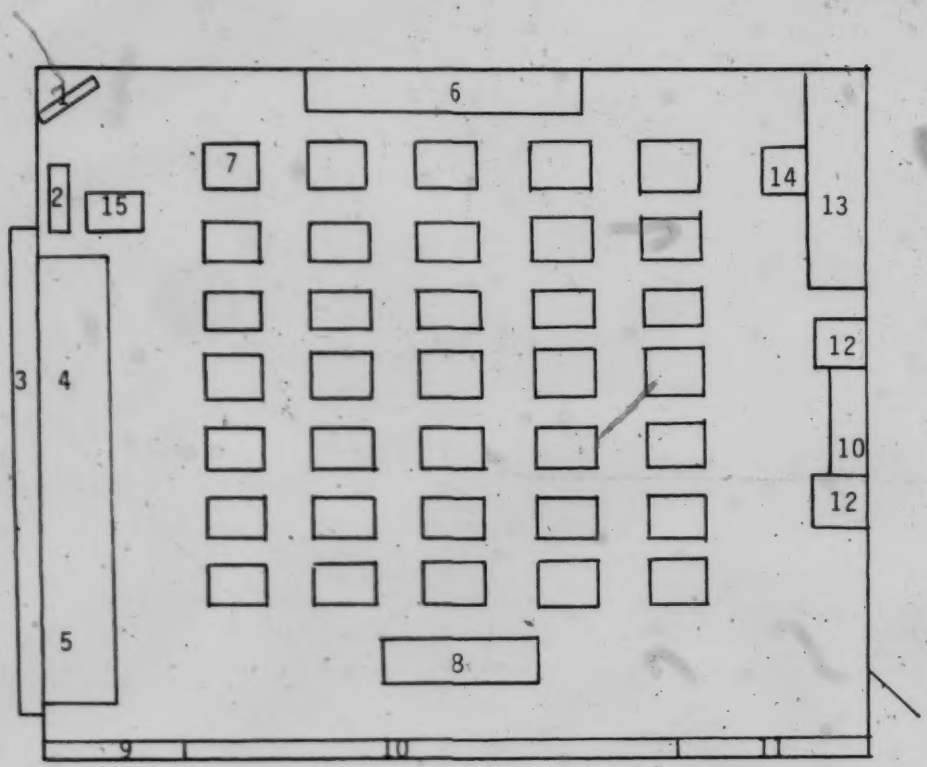
The schedule of classroom activities concerning cellular respiration was:

Monday, 5 October 1981: Students finished work on photosynthesis; received 'unit' on cellular respiration.

Tuesday, 6 October 1981:
- Introductory lecture
- Film entitled "Photosynthesis and the Respiration Cycle"
- Brief lecture on three appendices
- Students worked individually on objectives from textbook.

FIGURE VI

Plan of Biology 30 Classroom



Key

1	Charts on stands	9	Bulletin board
2	Movable chalkboard	10	Chalkboard
3	Mural	11	Bookcase
4	Table	12	Filing cabinet
5	Biological models	13	Cupboard
6	Trolleys with grow lights	14	Overhead projector
7	Pupil's desk	15	Researcher's desk
8	Teacher's desk		

Wednesday, 7 October 1981:	Part I of slide-tape presentation, "Cellular Respiration: Energy for Life" Lecture on objectives 1-3 re. digestion, anabolism Lecture on Appendix I, glycolysis
Thursday, 8 October 1981:	(Photosynthesis review) Part II of slide-tape presentation Lecture on Appendix I, glycolysis
Friday, 9 October 1981:	Test on photosynthesis
Monday, 12 October 1981:	Thanksgiving Day—no class
Tuesday, 13 October 1981:	Lecture—review of Appendix I, glycolysis Appendix II, citric acid cycle Appendix III, hydrogen transfer system Students worked on objectives from textbook.
Wednesday, 14 October 1981:	Students asked questions on objectives 1-14.
Thursday, 15 October to mid-November 1981:	Individual student project
Friday, 23 October 1981:	Test on cellular respiration
Monday, 26 October 1981:	Students received test results.
Thursday, 29 October 1981:	Mrs. T. returned and reviewed test.

Difficulty in Relation to Classroom Activities

The three teacher-planned activities which took place in Mrs. T.'s Biology 30 class while studying cellular respiration were: working on objectives from the textbook, lecture and watching audiovisual materials such as a film and a slide-tape presentation. Students expressed various opinions about these activities and whether they were easy or difficult.

Objectives

Most students expressed the view that they did not enjoy working on objectives from the chapter on cellular respiration in the textbook, Biology, by J. W. Kimball. The chapter in question was eighteen pages long and included eight figures and a number of chemical equations. The main reason for students' views appeared to be having to 'sift through' much detail in order to find the answers to specific objectives. They said:

"It's just flipping through pages and pulling out the words."
"You don't want to have to sift through all this stuff. It's just boring."
"Ploughing through stuff that's going to confuse you anyway."
"Too much digging to find an answer. If they want to, give me a fact, don't give me a bunch of crap with it."

Students generally felt that the textbook was difficult to understand due to its complex vocabulary. One individual described it as 'technical' and 'university'. Comments included:

"This textbook is sort of hard to understand because they use big wordy explanations for things."
"It looks like the textbook should be read from cover to cover, and we drop in places so they use words that you don't know. So in one sentence you end up looking up three different words just so you can understand it. That makes some sentences not worthwhile."
"Maybe we're not very good readers but I find it really confusing the way they explain things. Sometimes it's almost like they're not getting right to the point; they go around things and they put in extra words that don't really need to be there."
"They try to explain something and they still explain with long words."

Students are expected by Mrs. T. to answer the objectives listed in their unit (See Appendix VI), and a certain amount of class time is devoted to this. One class period was also spent in students asking Mrs. T. to answer or clarify these objectives. Mrs. T. has told students that she wants them to do their objectives before the lectures so that they have some idea of the content and have a basis from which to ask questions. She stated:

"I like to always have them make their notes before I start lecturing so that again they have some background information and they can ask questions of me in lecture, if they are so prepared. That's my intent in having them complete their notes first so that they know something and they can ask in lecture."

As this routine had been established since the beginning of the semester, students were aware that the objectives would be dealt with in class during lectures, and some therefore considered struggling to answer

them individually a waste of time and effort. This is illustrated by one particular pupil's remark:

> "I don't know but it's kind of not too pleasant that book, but then you get the answers, things that you didn't know from Mrs. T. in the class so it doesn't really matter."

Students also expressed the view that understanding the textbook was difficult since they could not ask for something to be re-worded or re-explained. The words remained the same, no matter what.

> "With the objectives, it's on your own and then if you're confused you can't do anything except look in the book and you can't find the answer."
> "When you're reading the book you can't really ask it questions. If you don't understand it then there's not much else you can do about it."

Mrs. T. perceived the text as somewhat advanced and empathized with the students' frustrations. She stated:

> "Another thing which might make it difficult for them is the way it's covered in the textbook. It's very confusing, very slow reading. I mean reading about chemical reactions for most students is just not very exciting because it's nothing that they can see."
> "...doing it on your own in a textbook, the lines don't change, the explanations don't change. They stay the same."

However, she expected students at least to attempt to answer the objectives and felt that it was important for them to be able to extract information from books since they are such a useful source of stored knowledge.

Despite student complaints concerning working on objectives from the textbook, they appreciated the way the objectives were stated for them in the unit. This provided them with a framework for study and ensured that they were aware of Mrs. T.'s expectations. Comments concerning the way the objectives were laid out included:

> "It makes it easier to study because you know what you have to know instead of just reading out of your textbook and you don't know exactly what's sufficient."
> "I like it. A lot of teachers say, 'You've got thirty pages. Make your own notes.' Well that's fine but what I think or consider important he or she might not and you get to the test and I might know

some things really down pat but the things that are on the test I don't really give a lot of work. So I like the objectives and the way she says, 'Well, I consider this important.' You can look for the idea on the test paper. It gives me a break."
"This way we know exactly what we're to learn."

Such remarks illustrate pupils' beliefs that having objectives stated made studying cellular respiration easier. This matched with Mrs. T.'s views on their use when she described them as providing the student with a guide to what exactly is to be covered in the unit. She recognized that otherwise students have a hard time determining what is and is not important. The objectives "give them a more clear view of exactly what the teacher expects of them and how they should be learning that material."

It appears therefore from statements made by students during interviews that they find the textbook difficult to understand. This was attributed mainly to the vocabulary and also to the amount of detail. Although students realized that they were expected to answer the objectives on their own, many did not do this before Mrs. T.'s lecture, since they knew that the answers would be provided by her in class. Some did not even attempt the objectives. Others tried them but upon encountering difficulty, for example when they were unable to find the answers, became frustrated and turned away from the problem. It is possible that to all of these students what they were asked to do seemed like an unnecessarily difficult experience which did not warrant the effort required. They therefore turned away from it in the knowledge that Mrs. T. would tell them the answers later in class.

Lecture

Students perceived lecture as the most beneficial of the three classroom activities which took place while cellular respiration was

being studied. Mrs. T. used the chalkboard and/or overhead projector, gave lucid explanations and continually questioned students to check their understanding. Students commented thus on lecture:

> "I'd say what I get most out of is probably a good lecture, just because you can ask questions. You can say, 'Well, I don't understand this' or whatever. With a film or a textbook you can't do that; you can't stop it, so I think I like the lectures best."
> "I think I learn a lot when she lectures because then she goes over the things and she explains them really well so that I know."
> "Things are cleared up the easiest for me when she's lecturing because she explains everything in detail and it makes more sense that way."
> "When she explains it you can think, 'I don't understand that, why's that going on?' and you can ask and she'll tell you why."

It is evident from some of these statements that students appreciated the two-way communication that results from being able to ask Mrs. T. questions and have her reply. Both here and elsewhere this was contrasted with the textbook and/or audiovisual presentations.

During the lectures, Mrs. T. used questioning for a number of reasons such as to evaluate student understanding, to keep students alert and to 'draw back' those whose minds appeared to have wandered, those who were chatting or those who looked confused. Some pupils were of the opinion that the major reason for her asking questions was to find out who had done their objectives. Most agreed that it kept them alert; for example, one student said:

> "I can't fall asleep now! If she asks me I won't know the question.. The poor sucker who gets the first question is always caught off guard, but it's always an easy question."

Students also described how they felt when they were questioned:

> "You always feel on the spot when you're questioned. Everybody's looking at you, everybody's waiting for you to make a fool of yourself."
> "She caught me off guard. I didn't know what she was asking. I knew what it was but I couldn't remember what she'd asked me. I didn't know. It was so stupid. I felt stupid because I know when

> other kids in the class get a simple question and they don't know, I just sit there, 'Oh what dummies' and, you know, it's simple. It wasn't hard."

Another expressed her experience when Mrs. T. was questioning students on objectives which should have been previously completed:

> "When she was going over those questions, I was just kind of 'I hope she doesn't ask me' because I didn't have it done. It was a bit confusing because I hadn't read anything."

and another pupil wrote the following:

> "I have a terrible fear of speaking in front of the class so I live with constant difficulty and fear of being asked for an answer."

Such quotations suggest that questioning achieves the intent expressed by Mrs. T., namely to keep students' attention. The statements also reflect students' concerns with appearing foolish or dumb in front of their peers as well as the tension of the situation in which students fear that they will be called upon to answer and know they would be unable to do so. The final comment speaks of a very deep and ever present sense of anguish which is constantly experienced by one particular student due to a fear of speaking in front of the class.

In general, therefore, lecture was the most popular classroom activity; and one of the major reasons for this was that Mrs. T. could be asked to answer specific questions, thereby providing clarification where necessary. Her use of the chalkboard facilitated note-taking, and students felt that her explanations were clear and easy. Being called upon to respond to questions caused some pupils difficulty in terms of being afraid of losing face in front of their classmates; and this produced a certain amount of tension. Although students expressed the view that some parts of the lectures such as the appendices (See Appendix VI) on glycolysis, citric acid cycle and hydrogen transfer system were detailed

and hard to follow, lecture was by far the most preferred classroom activity. It appears from student comments that this was due mainly to the possibility of engaging in dialogic communication with Mrs. T., as contrasted with the lack of two-way interaction within the context of working on objectives from textbook and watching audiovisual presentations.

Audiovisual Presentations

A film entitled "Photosynthesis and the Respiration Cycle" and a slide-tape presentation entitled "Cellular Respiration: Energy for Life, Parts I and II" were shown during the unit. Students' opinions on these were more varied than with either of the previously discussed activities. Some felt that they were very useful and facilitated understanding, while others described them as boring. Positive comments included:

> "It was simple to understand."
> "The slide presentation was very good. It discussed the objectives of respiration with ease."
> "They are helpful."
> "Again the well made slide show made it much easier to understand."

There was also a general feeling that audiovisual material was more realistic or as one particular student said, "more to life" since "seeing people and stuff is more true than looking at a page and reading that it gives you energy. You remember it." Mrs. T. expressed this in the following way:

> "Often a film or a slide-tape presentation is a moving, a motion—not so much a slide-tape presentation as a film and I think just the change in voice, the fact that there's a bit of colour and a bit of examples given as it's gone along instead of the black and white type of thing that the overhead transparency of the blackboard gives. I think those sorts of things add to the concept, that it isn't just a textbook, only textbook, only blackboard work. It adds a bit of colour, a bit of life to the presentation and to their understanding of respiration."

On the negative side, however, a number of students expressed the view that audiovisual presentations can be boring. They stated:

"Films and stuff like that makes me fall asleep. . . They're mostly repeated stuff so usually when the lights are out, you know!"
"I think it hashed over a lot of stuff we've already seen; like what's his face, the jars. We saw that about three times already."
"It was boring at times because we saw the same things."
"A lot of stuff in the filmstrip wasn't, like we're not going to use it or anything, like about the early experiments and stuff, it was kinda dull. . . First thing in the morning it's hard to sit there when you're half asleep and watch a filmstrip like that."
"I don't like the slides or filmstrips because most people just sit there and they start falling asleep. They have really simple stuff on those filmstrips."

The last of the above comments relates to the perceived ease or difficulty of the audiovisual presentations. It appears that the student who made the remark felt that the subject matter in the filmstrips was often too easy. Many statements made by students in this context reflected a concern with the level of the material presented. The majority of students who were interviewed expressed the view that both the film and Part I of the slide-tape presentation were easy and useful as introductory material to the unit on cellular respiration. Comments on these included:

"It was good for the first day of respiration. Much deeper would've been too much."
"It was easy to understand. It didn't go too deep into respiration, though. It sort of skimmed the surface."
"The slide-tape presentation was very good—easy to understand."
"It wasn't too hard to understand. It was not very interesting."
"It was pretty clear."

Mrs. T. also described this material as introductory and straightforward. Thus her perceptions were similar to those of her students with regard to these two presentations.

However, she did not anticipate, nor was she aware of, the problems experienced by students with Part II of the slide-tape "Cellular Respiration: Energy for Life." Most pupils with whom this was discussed expressed the opinion that the material was presented too fast and was hence difficult to follow. They made statements such as:

"That slide-tape presentation that we had confused me more than it helped me because I didn't know anything about it and then we were kind of put in the situation and I was just kind of 'O no, what's going to happen next?' kind of thing, but if we would have had it at the end I would have understood it all. But because we had it at the beginning, it was so confusing. I thought, 'We have to learn all this?'"
"They go so fast and it's hard to pick out what facts you need."
"We hadn't wrote anything from the books so I found it really difficult."
"That part that went through all the reactions. I just wrote the first section and then I just couldn't comprehend it. It was just going too fast."
"I think it would have been better to discuss what was going on before we saw the film because you need something to relate what you are seeing on the film to."

It appears that Mrs. T. did not perceive Part II of the slide-tape in the same way as the students did. She was not aware that they found the material difficult and she described it as going over "in a little bit of detail various chemical reactions which I was going to go over in greater detail later."

In general, therefore, students' views on the use of audiovisual presentations were mixed. In some cases they made the material easier to understand and made it seem more real, whereas in other cases the level of the material was either too easy or too difficult, or the presentation was perceived as repetitive and therefore boring. These factors varied both according to the individual student and the presentation in question.

Summary

Particular teacher-planned classroom activities provided the context within which students experienced difficulty in the cellular respiration unit. It appeared that they perceived working on their objectives from the textbook as difficult and disliked doing this. The vocabulary of the textbook was described as complex or university, which made it hard to understand; and some students expressed the view that sifting

through it to find the answers to specific objectives was both frustrating and ultimately a waste of time and effort since Mrs. T. would explain the same material in a later class.

Lecture was perceived by pupils to be the most beneficial activity. They felt that Mrs. T.'s explanations were clear and they appreciated the opportunity to ask questions. This possibility of asking questions when they did not understand appeared to lessen their difficulty to some extent although some particular material such as the appendices were complex and hard to follow. Some students described feeling embarrassed when unable to answer a question, or scared of being unable to do so and hence looking foolish in front of their peers.

Students' opinions on audiovisual material varied according to the particular presentation. Adjectives used to describe them included: helpful, simple, true to life, boring, repetitive, easy and difficult. The one which was described as most difficult, namely, Part II of "Cellular Respiration: Energy for Life," confused students by presenting too much material in a short time.

Factors Affecting Perceptions of Difficulty

A number of factors emerged as affecting students' subjective perceptions of difficulty within the unit on cellular respiration. For the sake of convenience these have been organized around a number of themes although it is evident that some are, at least to some degree, interrelated.

Complexity, Detail and Memorization

A factor frequently referred to by students when accounting for difficulty was the amount of detail and the complexity of the unit on

cellular respiration. There are a large number of chemical reactions involved in all stages of the process and it was these that students were alluding to when they spoke of the unit being complicated or detailed (See Appendix VI for unit on cellular respiration). The following comments reflect a concern with the amount of material to be learned:

> "It's a little bit more difficult than the other units because of all the steps involved, all the processes, but it's not too bad. It's more complex; there are more steps to the reactions."
> "But when it gets into the big diagram it's still a bit confusing because there's so many things happening in it at the same time."
> "The most difficult part of this unit is attempting to learn all the names of all the parts of the three different components of cellular respiration."
> "The most difficult part of respiration, I felt, was the first time I saw the charts on the three processes. They looked very complicated."

Complexity and the sheer volume of material to be remembered, therefore, appeared to be important influences on students' perceptions of difficulty.

Furthermore it was necessary for pupils to memorize the multitude of specific chemical reactions in order to be able to answer the test questions. They stated:

> "I still feel, though, that they will be hard to memorize for the test."
> "It's just that there is a lot of memorizing to it. There are a lot of steps and formulas to remember."
> "I haven't memorized the entire cellular respiration pathway and I think that it could be quite a task."
> "It's hard to remember everything, get everything straight."
> "So far it's been a little bit difficult because there's so much material, so much to memorize and the different steps are confusing."
> "I don't mind memorizing facts but memorizing the cycles gets to be a bit tedious because you can forget a thing really easily or miss out things really easily because there's so much to remember."

Students were concerned, therefore, that they had to memorize the exact processes involved in glycolysis, the Krebs' cycle and the hydrogen transfer system and that these had to be remembered sequentially.

Mrs. T. appreciated that the quantity of memorization involved in this unit caused problems for some students. This was illustrated by her remarking:

> "There is a lot of memorization involved, memorization of chemical reactions and that is difficult; that's difficult for a lot of people."

However, she felt that the only way to learn the material was to memorize it and at one point during the unit she suggested that students sit down that evening and learn it off by heart. It therefore appeared that Mrs. T. felt that there was no way to avoid having to memorize this material since this was the most effective way of learning it.

Terminology

Terminology was also described as an adverse influence on students' perceptions of difficulty in the cellular respiration unit. They made statements such as:

> "Something I found rather difficult in this cellular respiration unit was actually learning all the specific names of the substances involved in the reactions and the order in which they are produced."
> "There are so many new names."
> "The Krebs' cycle was a little more difficult because of the names of all the acids you have to remember as well as their location on the cycle."
> "I'm starting to run into problems with terminology in trying to keep the names of various reactions and chemicals straight."
> "The only part which might be thought of as being difficult was having to memorize the names of the acids in the Krebs' cycle as well as their location in the cycle."

In addition to learning the names of the various chemicals involved in cellular respiration, some students were confused by the different names for the same process; for example, the Krebs' cycle is equivalent to the citric acid cycle and the hydrogen transfer system is equivalent to the cytochrome enzyme system. Students remarked:

> "Multiple names for the same reaction is confusing."
> "There are also so many different names for the process it makes it harder to understand."

One particular student gave this description:

> "I think it's going to be tough, a lot of terms, big words. . . . like PJAL, stuff like that. It's a lot to learn, to learn the words and then you've got to learn the spelling of it and you've got to learn its function and so much stuff about it that you end up getting bored with it almost."

Illustratively, the student's use of PJAL is incorrect since the chemical in question is PGAL or phosphoglyceraldehyde.

Chemistry

Students often referred to the amount of chemistry involved in the unit on cellular respiration, inferring that this was one of the factors that contributed to their perceiving it as difficult. Comments included:

> "It's kind of confusing, all the chemical reactions."
> "For the people that take chemistry, they can understand it."
> "I think the kids that have taken chemistry before end up with an advantage."
> "I've taken Chem. 20. I've got Chem. 30 next semester, so it helps but it still makes it a little bit tough."
> "I think chemistry helps a lot, too, having the background behind it because this way they don't really explain. Like if somebody takes Biology 30 before Chem. 30 then biology would help in their chemistry in that way because they've heard of it before but it's not as thoroughly explained here."
> "I think the hard part was reduction and oxidation and redox reactions because we took that in Chem. 30, but someone who hasn't taken, like I've finished Chem. 30. Most kids haven't so they don't know what it's talking about because I know in Chemistry I was confused. It's barely been taught about in biology. You almost need it."

In these ways students made it clear that they felt that background in chemistry is beneficial for understanding cellular respiration. Those who had completed Chemistry 20 expressed the view that this was helpful, although the most relevant material, namely redox reactions, is covered in Chemistry 30. Mrs. T. sympathized thus with students who felt threatened by the large number of chemical reactions inherent in the topic of cellular respiration:

> "Biology 30s tend to view a lot of chemical reactions as some awesome, terrible thing. I think reducing things down to chemical reactions somehow makes it non-biology, makes it chemistry and it is not necessarily interesting to some of them. . . They're a little bit fearful, a little bit wary of the detail because this is biology and not chemistry, so they tend to get lost in the equations."

Both in interviews with the researcher and in class, Mrs. T. expressed the view that students feel that the chemistry involved in cellular respiration is more complicated than it actually is. She attempted to allay some of the students' fears in this regard by stressing that the use of chemical symbols is a logical system designed to simplify rather than complicate or confuse.

Relevance and Interest

It became apparent that most, if not all, students preferred to study topics which they felt were relevant to their everyday lives and they perceived these to be easier than other topics. The notion of relevance emerged during many interviews and therefore appeared to be of some importance to students. They expressed the view that biology is generally of greater relevance than other science subjects such as chemistry, physics and math. This is reflected in the following statements:

> "I know a lot of people don't like math which is understandable because a lot of the time you don't use, like sequences and series is what we're taking now and I can't see how I would use that in my normal, everyday life."
> "I knew for a fact I'd probably never use chemistry. Like if you really sit down and try to think where are you going to use it unless you're in a lab."
> ". . . whereas biology you can actually get almost something practical out of it. It's more interesting, beside I like biology and social studies and English and stuff. They're just real."

Two of these quotations illustrate the students' concern with the utility value of school knowledge. They believe that what is learned should be of practical value in their life and, on the basis of this,

reject both sequences and series and much chemistry as irrelevant. With reference to cellular respiration, another student remarked:

> "The specific cycles and stuff, I don't really see the use of it, like if somebody's not going to university and then go into it in more depth and make a career out of something to do with biology."

This particular student, in concurrence with many others, was having difficulty seeing the use of studying cellular respiration in such detail since it was viewed as abstract and unrelated to everyday life. Although some did appreciate its necessity for the maintenance of life, they could not see the relevance of the detailed chemical reactions which they were required to study. The notion of utility was also illustrated by the pupil who said, "I think it should be related because if you have no use for it, why study it? You don't really want to know it."

Another interpretation of relevance appeared to be whether what was learned enabled the student to know more about his or her own body. Students remarked:

> "It's interesting learning how everything works."
> "I thought it was really interesting to understand what your body was doing."
> "What makes it a bit easier is that I find it quite interesting discovering just how it is we function as human beings."
> "Just learning how everything works is kind of neat, too";

and with specific reference to the cellular respiration unit, one student said:

> "Well, it does have a little bit to do with you. It's interesting in the way it happens in you and everything, so it's not that bad."

Here again it seemed that although generally students appreciated learning about how their bodies work they felt that reduction to the molecular level (as in the case of cellular respiration) was unnecessary.

One further understanding of relevance relates to when what is being learned "answers questions you thought about." One of the few

topics mentioned during the cellular respiration unit which particularly interested students and which they could relate to their everyday lives was the role of lactic acid in causing muscle cramps and stiffness. Students commented:

> "I found it really interesting. I'd always heard about lactic acid and how you're not supposed to get a build-up of lactic acid, and I never knew what it meant really; just knew I'd always heard the word. I thought that's pretty neat."
> "The lactic acid part, cramps. Yea, I liked that. That would seem pretty practical, whereas physics and chemistry you're just sitting there and okay, I'm learning all this and I'm passing tests. Am I ever going to use it? And Jeez, I've got lactic acid all over my legs and I'm getting cramps."

These remarks appear to illustrate how the discussion elucidated something that students had previously heard of but not understood.

One specific student in the group that was interviewed daily had been really 'struck' by a horse shown in the film to illustrate the use of energy produced by cellular respiration. She said: "Even that horse. That's what hit me the most, the horse. That's what respiration is, the fuel he uses, the energy to pull the plough." Other students also appeared to relate to this and from this time, 'the horse' became an in-joke with the group and they constantly reminded her of it. A further example was a diagram that showed how body protein can be used up to provide energy in cases of severe malnutrition. One pupil stated:

> "Also when they showed the pictures of all the people with the protein inside. That was really good. Why the kids are so weak. You always hear that it's eating away their body but what is eating away?"

Each of these examples interested students since they concerned phenomena with which they were already familiar from their everyday experiences. They had seen or heard of such things and were now learning the reasons to explain them. At moments like this biology really comes to life for

the students. It makes sense to them since it contributes to their understanding of their own bodies and life around them.

Mrs. T. realized that the abstract nature of the unit on cellular respiration influenced students' perceptions. She stated:

> "It's difficult to get excited about it because in the organ systems you can draw on examples of diseases and all of them know someone who has diabetes or has had a heart attack or a stroke and there are many things that are significant to their own lives that can be brought in, whereas cellular respiration, you can talk about the cyanide poisoning and fluoride poisoning and really that's about the extent. . . If a topic can be made very, very practical in the idea that they can see or experience something, for example in the circulation unit, blood pressure, heart rate. Those are all things they can see and experience and therefore they're very easy to teach in the form of demonstrations and labs as well as lecture. Cellular respiration is something that is a little more difficult to see and to demonstrate."

These reflections by Mrs. T. illustrate her awareness of some of the problems inherent in teaching cellular respiration, namely the fact that it is not closely related to anything in the student's normal everyday experience. She reveals her own view of the topic when she describes her difficulty in getting excited about it due to its lack of relevance and abstract nature.

Behind many of the comments on relevance there appeared to be an implicit assumption that the less relevant a unit was, the more difficult it was. A number of students made explicit statements about this, for example:

> "If you can relate it to yourself, to something in your life, then it'll probably be easier to understand, but if it has nothing to do with you or anything, then you begin to say, 'Forget it, just shove it.'"
> "If you have just a little bit of interest in it, you want to do more and want to understand, but if you think it's totally boring you won't put any time into it or you don't even want to listen in class. This is boring kind of thing but if you have a bit of interest you'll probably do better and it won't be so difficult."
> "Probably it's both related. You don't think it's practical because you don't understand it. It makes no sense how you're going to ever use this when you're older, so it's probably difficult and so you think it's impractical and you don't try very hard or you don't

understand something so you think 'Well, what's the point of it?' So you think 'Well, I don't care so I'm not doing it.' I know that happens in math a lot, doing all these stupid equations that I'll never probably see after I get out of Math 30, so you think 'What's the point really?' So you don't understand why you should have to do this so it becomes more and more difficult and then when things get difficult you get frustrated and then you don't want to do it at all."

Relevance therefore appeared to be one of the most important factors which influenced students' general perceptions of a topic as well as more specific perceptions of how easy or difficult, interesting or disinteresting it was for them.

Time

A further influence on perceptions of difficulty within the unit on cellular respiration was time. In general, many students felt that insufficient time was devoted to the topic and that this contributed to its being difficult. Comments reflecting this included:

"I wish we could spend more time on each cycle."
"There are so many new names that were covered in such a short time that it was (and is) exceedingly difficult to understand all the steps of all the cycles. I recommend that the lectures move at a slower pace in future."
"One problem with this unit was that the different cycles were taught too fast. They should have spent more time on each."
"I think we're going a bit too fast because we only spent a little while. . .It was kind of rushed because then we have homework and there's not always time to do that much and then that's where you get lost."
"Too many facts presented in too short a time."

Thus students experienced a sense of being rushed through the unit and this increased their perceptions of difficulty.

Summary

It was evident from remarks made by both students and teacher that there were a number of factors which affected their subjective perceptions of what constitutes a difficult situation. Within the context of cellular respiration, the major factors were: complexity detail and

memorization, terminology, chemistry, relevance, interest, and time. Of these it appears that the majority are related to the inherent nature of the subject matter, whereas others can be described as related to students' attitudes and teaching situation.

Experiencing Difficulty

Metaphorical Descriptions of Difficulty

When asked to describe a difficult experience within the unit on cellular respiration, many students tended to focus on the content or subject matter that they found difficult rather than the experience itself. However, in doing so they used a number of phrases which referred to the living through of the encounter with difficulty and it is these that will be investigated here.

It appeared that the participants and, for a long while, the researcher, took for granted the nature of difficulty and assumed that others would understand what they meant when they used phrases such as "I was confused," "I couldn't get it" and "It didn't click." Towards the end of the situational study, the researcher began to question students more closely on the meanings of some of these expressions and found that in most cases students had difficulty responding. Quite often when asked for clarification in this way students hesitated to answer or replied, "I don't know." This gave the researcher the impression that the meaning of such expressions was usually taken for granted and it was assumed that no further explication was necessary since the other was expected to understand. However, a number of students, after thinking for a while, referred to their sense of frustration. This suggested that the notion

of frustration was probably important and it is therefore considered in some detail in the following section.

It appeared that for some students describing in words the meaning of difficulty was in itself a difficult experience. This may relate to its being a subjective and in many cases emotional experience which occurs in an existential sense prethematically, or prior to language. Therefore it is not easily expressed in words. By using the word difficult or phrases such as "It was confusing," individuals name the experience but at the same time gloss its meaning. Socrates has suggested that words have the power to both reveal and conceal. Thus in a way language objectifies and even reifies the notion of difficulty. It invokes an intuitive sense of meaning which it is the task of the researcher to attempt to reveal or disclose by getting beneath the words to their very grounds.

A number of common themes emerged from participants' descriptions of experiencing difficulty. There were nine phrases or words which were consistently used when students were discussing difficulty within the biology curriculum. Of these, six were metaphorical, five, visual and one, auditory.

Being Confused

A very important theme was the notion of confusion. Students saw a close relationship between experiencing difficulty and being confused. With regard to various aspects of the cellular respiration unit, they said:

> "I got really confused."
> "I find it really confusing."
> "When I read the book I get all confused. Then I have to get Mrs. T. to explain it so I can get unconfused."
> "It was just sort of confusing in my mind."

Mrs. T. also used this notion when she made statements such as:

"Judging by questions that were asked individually, a lot of people were confused."
"The way it's covered in the textbook, it's very confusing."

On a number of occasions the researcher questioned students on the meaning of confusion, asking them to elaborate on what it is like. The following are examples of this:

Int: Another thing that you mentioned before was feeling confused, or feeling a certain amount of confusion. Can you say something more about that, like what it is like to feel confused?
St.: What it's like (laughs) to feel confused. You feel confused (laughs).
Int: Right. I really do have a habit of asking some awful questions. (Both laugh.)
St: It's more of a, hard to say, when you're confused. It's actually a bother that you get confused because you didn't get it the first time so you just, it's a hassle; it's a bother. You have to go over it again, putting more effort into it to think, to understand it again.

Int: This concept of confusion keeps coming up. Now, if you're confused, what is it like? What is it like to be confused about something?
St.2: Frustrating.
St.4: Yea
St.2: I get so sick of things when I'm confused that I just can't handle it.

Int: It's tricky, I know, but I'm trying to get you to think a little more about what it's like to be confused, not in terms of content, not in terms of material like the ATP going here or there or the hydrogen atoms going here or there, but in terms of what does it feel like for you to experience that confusion.
St.3: It's kind of frustrating because you know you should know it. I should know this but I don't.

Each of these examples shows that for students being confused is a frustrating experience, and yet it appears that referring to the sense of frustration does little to illuminate what being confused is like.

Clearing Up

Certain comments regarding "clearing up confusion" suggest that there may be some form of dialectic between confusion and clarity, and

that being confused about something involves it being unclear. When things are unclear they are difficult, whereas, as they become clearer, they become easier. Some students noted:

"It sort of clears up in your mind."
"It sort of made things more clear."
"We cleared everything up."
"Mrs. T. would clear everything up." and others explained:

"It all comes into focus."
"It set a lot straight in my mind."
"Trying to keep the names straight."
"It's hard to get everything straight."

It is interesting to note how all these phrases are visual metaphors which refer to seeing. The notion of something clearing up assumes that it either is presently or has been unclear, for example, obscured by a thick and swirling mist. The mist temporarily hides what is 'out there', possibly causing the person to exclaim, as one of the students did, "I can't see what's going on." However, as the mist begins to clear, what was previously concealed is gradually revealed to the person in question. The difficulty is experienced in the clearing up or the coming to clarity. When things have become clear, they are no longer difficult.

Making Sense

The notion of sense-making was frequently used to describe encounters with difficulty in the context of the biology classroom. When students were confused and the material unclear, they spoke of it making no sense to them, for example:

"We went through it but it didn't make any sense at all."
"She explained it to me but it still didn't make sense."
"The appendices just didn't make sense to me."

Unfortunately, the researcher was unable to gain a deeper understanding of the meaning of sense-making to the participants. This occurred mainly due to her unquestioning acceptance of the phrase, and could have

been overcome by having asked the students to elaborate on their meanings.

Figuring Out

Students also spoke of difficulty as being unable to figure something out. This is illustrated by:

"I was trying to figure it out myself."
"I can't figure it out."
". . .trying to figure out what's going on."
". . .trying to figure out when they start and when they stop."

Unfortunately, in a similar way to 'sense-making', the researcher did not manage to get beyond the phrase 'figuring out' to a deeper sense of what it meant for the participants. She was operating on the taken-for-granted assumption that she understood its meaning, whereas, on further reflection, she realized that this was not so.

Grasping

Another way that both students and teacher described the experience of difficulty centred around the notion of getting or grasping ideas or concepts. Statements reflecting this include:

"I couldn't quite get that."
"I had to get it in my mind."
"If I get at least parts of it from classroom work. . ."
"Reading it, I usually don't catch what's going on."
"A few people are beginning to grasp the idea of what is actually happening."
"Some people haven't grasped the concept just yet."
"They were just picking it up for the first time."

The metaphorical use of such terms as catching, grasping and picking up are of interest since they assume that whatever is picked up or grasped is within reach. In order to grasp something, the person must reach out for it. There can be no grasp without a reaching out, a stretching or extending the boundaries of one's body. By reaching out towards something individuals extend the limits of their lived space. The grasping involves

contact between part of the subject's body such as the hand and an object such as a ball. At the moment of the catch, hand and ball meet both in time and space. They come together, the hand enclosing the ball, possessing it and taking it in towards the body. By using this phrase, students suggest a similar relationship between themselves, the "I", and ideas or concepts. There must be a reaching on their part before the ideas can be grasped or picked up. Difficulty is experienced in the reaching out towards the ideas, and is resolved when they are gotten or grasped.

Clicking

A number of students described the experience of difficulty in terms of clicking. They said:

"I'm beginning to understand them now because they're slowly clicking."
"It doesn't click."
"It just doesn't click at all."

Before the click occurs, the student experiences difficulty, whereas, after the click has taken place, the difficulty ceases to be. One of the assumptions behind this particular metaphor appears to be that the click either does or does not occur and that it does so at a particular point in time. Unlike the notion of clearing up, which suggests a gradual process, the idea of the click is more absolute since it occurs at one particular point in time.

Sinking In

Pupils used the idea of subject matter sinking in when they stated:

"After it's explained, it usually sinks in."
". . .that it's not sunk in just yet."
"It takes a while for some of this stuff to sink in."

Sinking in suggests, at least to the present researcher, a passive process that occurs across time and space. For example, ink sinks into a

blotter gradually and as it does so the ink spreads out from one spatial location to another. Student comments suggest that the difficulty is experienced within the time taken for the material to sink in and that, once it has sunk in, the difficulty is over.

Fitting Together

A very frequent and apparently important notion that emerged concerning the meaning of difficulty within the context of cellular respiration is that of being able to fit things together into a meaningful whole. Again and again students used this metaphor, and it is also interesting to note that they requested from Mrs. T. a chart showing all three appendices together and their interrelationships. The appendices had purposely been given separately in order to simplify the material for the students but it was evident that they were having difficulty in being able to see how the three different processes involved in cellular respiration fitted together.

Some of the numerous comments made by students regarding the notion of fitting together are:

> "I just found it difficult figuring out how different things fit together."
> "It ties everything together."
> "Now all I have to do is to be able to put them together."
> "The only difficult part was to try and analyze the charts and establish how they fit together."
> "You don't know how they work together then, but then you can piece it all together."
> "That's where I have problems is relating them to each other, like I'm reading through and I understand this but I don't understand how it relates to this."
> "It confused me how it works together and how they were connected."
> ". . .so I can piece it together a little bit easier."

The way in which students spoke of fitting things together suggests that they perceived the various processes and reactions involved in

cellular respiration as pieces of a jigsaw puzzle. They were encountering difficulty in trying to see how the pieces fitted together into a meaningful whole and this required understanding how the various reactions were interrelated. An interesting analogy is the notion of the hermeneutic circle whereby Hoy (1978) suggests that part and whole are related in a circular way. Hoy (1978) maintains that in order to understand the whole, it is necessary to have a prior understanding of the parts, and in order to understand the parts it is necessary to have a prior understanding of the whole. It appeared from students' comments that their main difficulty was in being able to tie the parts of cellular respiration together to form a meaningful whole; although, if Hoy (1978) is correct, it may not be as simple as this since there may be a dialectical relationship between parts and whole.

Being Lost

A number of pupils as well as Mrs. T. used the idea of being lost to describe experiencing difficulty. They stated:

"I got lost completely."
"Then you're kind of lost, too."
"People are going to get lost."
"They tend to get lost in the equations."
"I think that the majority of them are a little bit lost right now."
"I'm getting nowhere."

Let us imagine for a moment being lost somewhere, perhaps in a dense forest, and let us ask what it is like to be lost. I lack direction, either knowing where I want to go but finding myself unable to get there, or not even knowing my destination. With this lack of sense of direction comes a sense of anguish, of fear. I do not know where I am, neither can I know where anyone or anything else is. The world has ceased to be as I normally experience it. I am truly alone. There is myself and my fear

only. I begin to wonder who I am. If I do not know where I am, can I in fact know who I am? I start to panic. What should I do? At least I am free to decide that; free to choose my action, which way to go. I may reach a path or a crossing of ways. Which way should I turn? How should I decide? Maybe it will lead me nowhere, round in circles, back to where I am, lost. I become tired of struggling on, ever forward. What really is the point? Perhaps I should just sit down, remain exactly where I am, lost. Which ever way I turn I seem to get nowhere but rather become more and more lost. Does it even matter that I get out of here? I am too tired to go on. I will stop here. I will not go one step further. I will not take any direction at all. I am hope-less. And yet there is something that draws me on, that invites me to keep moving, ever onward. The future beckons to me, encourages me to have hope. So on I wander, not knowing exactly where my journey will lead me, knowing only that I must keep moving beyond myself, staking out new paths in the hope that I will find my direction and, through it, myself.

It appears that when biology students used the phrase 'being lost', they were referring to being lost in relation to the subject matter. They lacked direction in terms of not knowing which way to go and experienced a growing sense of frustration in the realization that they were not reaching their anticipated destination.

Summary

It is interesting to note that most of the phrases used by participants to describe difficulty as experienced in the biology classroom are metaphorical. The ones which are not are the notions of being confused, making sense and figuring out. Other themes were: clearing up, grasping, clicking, sinking in, fitting together and being lost. In

particular, the idea of grasping seems important since, in a literal sense, it necessitates a reaching beyond one's normal limits. When related to the classroom situation, it suggests a reaching out on the part of the student towards the subject matter, an encompassing and a grasping; the difficulty being experienced in the reaching, resolved in the grasping.

In a somewhat similar way, certain other phrases suggest a dialectic between the sense of difficulty and its resolution—for example, confusion and clarity, nonsense and sense, being lost and being found.

Frustration as an Aspect of Difficulty

It appeared both from what was said, and in some cases how it was said, that for many students the encounter with difficulty was an emotional experience. Many described their sense of frustration at being unable to accomplish what they had intended. The present section attempts to examine more closely the idea of frustration and some of its aspects.

Trying

The notion of trying was frequently raised and appears important in this regard. Students mentioned:

"trying to keep the names straight."
"trying to figure out what's going on."
"trying to figure out when they start and when they stop."
"trying to fit everything together."
"I was trying to figure it out myself."
"The only difficult part was to try and analyze the charts."
"You've tried and you've tried and there's no way you can understand it."

The idea of trying seems to be rooted in doing. Students were trying to do something such as figure things out, fit things together, or understand, and their difficulty lay in being unable to achieve their

intents. Trying therefore implies a going beyond oneself or reaching out, an extension of one's limits that involves a moving forward. In terms of some of the phrases used by the students, the trying is an attempt to reach the click, the grasp, the clarity. However, in order to try at all, it was apparent that they needed to have hope that they could achieve their goals. The task to be attempted must lie within the realm of possibility.

Losing Hope

It seemed that the students were willing to try up to a certain point. However, at that point, when the trying became altogether too burdensome, a change in attitude occurred. They were prepared to struggle with the tasks before them and strive to reach their goals only so long as they believed them to be attainable. After finding their attempts constantly thwarted and progress at a halt, some gave up hope. At this point the task appeared pointless and students made comments such as:

"It seems like you're never going to understand."
"It can't be understood."
"I'll never know."

Such remarks reflect an increasing sense of frustration and hopelessness which resulted in their giving up.

Giving Up

As the sense of frustration mounted and students realized that they were unable to achieve their intents, many essentially gave up or turned off. The following statements reflect this notion:

"Let's just forget it."
"You just want to forget about it."
"You think to yourself, 'Forget it!'"
"You tend to turn off."
"There is no sense in listening."

"I guess you give up."
"I'm not going to do it."
"I usually feel like walking out right about then."
"You don't care any more."

These illustrate a turning away from the difficulty that faces them, and was generally accomplished either by putting the work away if at home or 'tuning out' the teacher if in the classroom. Such statements appear to show a sense of anguish on the part of the students and a refusal to proceed any further, to take the next step in the case of the 'being lost' metaphor. In most cases this took the form of postponing the work until another time and obtaining help on it; for example:

"Well, I'll just put a check mark by this one and ask her tomorrow."
"Yea, procrastinate."
"You say, 'I'll ask her tomorrow.'"

The following are a number of powerful descriptions of the sense of frustration and were obtained from students and teacher. The first student said:

"It seems like you're never going to understand it and then you think to yourself, 'Forget it. I'll never know. It doesn't matter.' Then I usually, I'm just not concentrating on what she's saying after that. I'm getting farther and farther and farther apart. I usually feel like walking out right about then just because it's frustrating. But it's not good because usually it just gets you in the sort of mood that you don't feel like doing anything for the rest of the class because you're so upset about that one thing."

The next description concerns an experience one student had while working on objectives from the textbook. She said:

"One night I was studying, or trying to, and I opened the textbook deciding to maybe jot down some notes. Reading what the text said made me extremely frustrated. That text is so condensed with huge terms, scientific language, that I didn't know what the hell was going on. You practically have to know everything that you've ever taken in biology to understand it. I hate that textbook. I'm no professor and I sure think I really need to know half that stuff

> they throw at you. If it was much more simple and basic and smaller steps, then maybe I wouldn't have thrown my text on the floor. Seriously, I know then I wouldn't give up so easily."

This description is particularly powerful since it reflects the student's deep sense of anger and frustration at the text. The last few sentences also suggest that at least some of this is directed against herself. It is interesting to note that the description was given three days after the experience but it is clear from the words she used and her tone of voice that the anger she experienced had in a deep sense remained with her.

Mrs. T. describes in a general way how an encounter with difficulty can produce a growing sense of frustration and the effect this may have on future experiences in the classroom:

> "You read a line in your textbook, you're reading it but it's not going in and so they read on and they find that they've read half a page and didn't understand a word and that's frustrating to have to go back and re-read the same thing two or three times, look at the diagram, try to follow the worded explanation with the flow diagram and it's frustrating. It's frustrating if they don't pick it up and I can see after going over it two or three times that you can get damn frustrated and not care any more and then when your teacher tries to explain it, have you wiped all that away? Are you now going to approach it with an open mind or have you convinced yourself that you can't understand that and therefore there's no point in trying to concentrate? It can't be understood. It can't be done, and I think that is what is happening to some kids. . .and doing it on your own in a textbook, the lines don't change, the explanations don't change. They're the same."

Summary

This section has attempted to show how difficulty is experienced emotionally, and to illustrate various phases of the frustration that accompanies it, at least in the present context. It was noted that students frequently spoke of trying to achieve certain intents and it has been suggested that the notion of trying is similar to that of reaching

beyond oneself. However, if students had tried and tried and were not being successful it appeared that they adopted a hope-less position which illustrated a resignation to the fact that the task was impossible. Based on this loss of hope, many students gave up or turned away from the difficulty, frequently postponing facing it until a later date and planning on asking their teacher for assistance. It also seems likely from some of the longer descriptions that the sense of anger and frustration experienced in such circumstances may remain with students for a while afterwards and affect their perceptions of the subject matter in a deeper sense.

Difficulty as a Mode of Being

The commonly held view of difficulty, as reflected in both the curriculum literature and the attitudes of teachers such as Mrs. T., is that it is a bad and undesirable experience which should be eliminated from the life-world of the child. In terms of curriculum, it is assumed that this can be achieved either by removing or replacing difficult material; and in terms of classroom presentation, by changing teaching methods. This position reveals, implicit in the desire to eliminate difficulty, a quest for comfort, inertia, the easy life. Some curriculum theorists and classroom teachers thus apparently take the position that students should not have to face difficulties; that learning should be made easy for them. Problems should be removed, and with them, the necessity to struggle or strive beyond what is already given. This approach thus helps to perpetuate the negative connotation that the notion of difficulty carries with it, namely, difficulty is bad; and encourages a

reluctance to admit to difficulty in the fear that it is a reflection of personal inadequacies. It appears, therefore, that the position which advocates the eradication of difficulty reflects a number of fundamental assumptions.

Firstly, it is important to reflect on the meaning of a life without difficulty. It seems, at least to the present researcher, that, if this were possible, it would promote a very superficial approach to the way in which life is lived. If difficulties never confronted us, we would most likely live at the very surface of life, thereby glossing its meaning in this regard. Rilke (1975) writes of "the surface (of life) covered with incredibly dull material, like furniture during a summer vacation." If life was always easy, we would never be given the opportunity to penetrate beneath the uppermost layer of our being. We would be condemned to live out our lives at the surface. Similarly, by eliminating any form of difficulty from our lives, we could not be presented with it as a possibility. Kierkegaard (1975) describes our sometimes desire for difficulty thus:

> "For when all combine in every way to make everything easier, there remains only one possible danger, namely that the ease becomes so great that it becomes altogether too great; then there is only one want left, though it is not yet a felt want, when people will want difficulty." (p.86)

The question concerning the possibility of eliminating difficulty appears to be an important one. In concrete terms, for example, in the biology classroom, even if difficult material such as cellular respiration was removed it seems likely that students would still experience some difficulty in the course. Although difficulty is not always present in our lives, it is always found, at least horizonally, as a possibility.

It is thus an ineradicable part of being in the world, without the possibility of which life would not be as we presently know it. Life without the chance of difficulty, therefore, is an impossibility. Most importantly, however, the aim for the eradication of difficulty and its conception in a negative light reflects a concern with making life easier and essentially seeks to deny that it can be a valuable and significant experience. It is this aspect that is of major interest to the present researcher.

It appears that the notions of trying and hope which emerged from participants' comments are related to different 'levels' of difficulty. For example, if something is perceived as impossibly difficult, we are unlikely to even attempt it in any serious way. Thus there must be a certain measure of hope which invites us on. Frankl (1963) writes of those in concentration camps during World War II without hope. They had lost the will to live and refused to get out of bed in the morning. In contrast to this, at the other end of the scale, it seems likely that if something is perceived as too easy it is not valued very deeply, if at all. In view of these reflections, the task of the teacher is then perhaps to ensure that students are faced with situations that are neither too easy nor too difficult for them but lie within the realm of possibility. This 'level' of difficulty may thus provide a challenge for them to grow beyond themselves.

In every case, difficulty is experienced by us as individuals and is found in our relationship with the world. Whether we are biology students being frustrated by the vocabulary in the textbook or prisoners of war struggling to survive and find a meaning in life, the difficulty facing us is unique and particular. It involves our being-in-the-world

and coming to terms with it. In difficulty as in joy we are essentially alone. Although we can discuss and thereby, to some extent, share it, the experiencing of difficulty is essentially an experiencing for me, or for you. I am the one who is in this particular situation and who must live through it. You are the one faced with that difficulty and you must live through it.

In some situations we can do nothing about the difficulty in terms of being able to change it and we have no choice but to accept it. However, what is always given along with the problem is the freedom of choice of position in the face of difficulty. Frankl (1963) states: "What matters above all is the attitude we take toward suffering, the attitude in which we take our suffering upon ourselves." The position we adopt and each action we take in our encounter with difficulty, as in any other situation, involves us in making decisions. In deciding our attitude towards difficulty we create our selves at every moment, since our actions reflect statements of our selves and our being in the world. What is required therefore is not a freedom from difficulty but rather a freedom for it, an openness on our part to take it in rather than shut it out, to take it in and see what we can do with it.

Difficulty can be seen as life's way of challenging us to be virtuous. It provides us with the opportunity for achievement in the sense of going beyond ourselves. We are free to accept or refuse the offer which is life's way of requesting us to reveal ourselves. Difficulty calls us forth, summoning us to move beyond our present selves, to become what we are not yet. Perceived in this way, difficulty, in whatever form it appears, gives us the chance to fulfil as yet unfulfilled

possibilities and invites us to penetrate ever deeper towards the grounds of our being. It challenges us to be and, more importantly, to become many things. Ortega y Gasset (1975) describes us as beings that consist in not-yet-being and it is towards the realization of the not-yet that difficulty draws us. It beckons us to fill the gap that exists between what we are and what we should become, between what we have achieved and what is still to achieve. We are challenged to have courage, tolerance, patience, to strive for what is 'good'. Thus, the presence of difficulty calls us forth to have the courage to face it, to persevere. Rilke (1975) writes:

> "If only we arrange our life according
> To that principle which counsels us
> That we must always hold to the difficult
> Then that which now still seems to us
> The most alien will become what we
> Most trust and find most faithful."

By challenging us to suffer bravely, to face up to our difficulties courageously, to be tolerant or patient, life holds meaning for us up to the very end.

Through our encounter with difficulty, life gives us the opportunity to reach beyond our limits, to show both others and ourselves who and what we truly are. The young woman who has just been told that she is dying of cancer, the parents whose child has been killed in a car accident, the wife who learns her husband has committed suicide, the little boy who falls from the tree while playing and will always be confined to a wheelchair. Extremely difficult situations such as these, as well as the more mundane examples which we encounter daily in our lives, invite us forward to move beyond our present selves and narrow the gap between what we are and what we should become. They help us grow perhaps

not upwards but deeper down towards the very roots of our being that anchor us in the world.

Difficulty is thus an essential mode of being in the world, an ever-present possibility of the living of life. If we seek to live authentically, we must expect to encounter difficulties which will involve us in striving to move beyond ourselves, to become what we are not-yet. Although the living-through of such experiences will unavoidably bring with them anguish and suffering, it will, by the same token, give us the opportunity to reveal ourselves. As Epictetus states: "It is difficulties that show what men are." In this way life challenges us to be virtuous and reminds us to have courage, patience, tolerance; to strive after whatever 'good' is summoned from us by the circumstances. It invites us onwards on our journey through life which is, after all, not a straight and even path that is easily traversed, but one that dips and curves, blocked here and there by obstacles that stand in our way. Although we may not know exactly where we are going, we are called by difficulty to life itself, to continually stake out new paths, and in this way difficulty both gives us a sense of what life is and beckons us ever onwards beyond ourselves.

CHAPTER V

REFLECTIONS

Experiencing Difficulty as a Search for Self

I encountered a number of "difficulties" within the context of doing the present research. Some of the more superficial ones can be easily named while others were of a much more significant and deep-rooted nature. Initially there was the problem of finding a suitably meaningful topic and deciding on my approach to it. Although it is evident that I adopted a particular position vis-a-vis my research, this is, by no means 'set'. In fact, the way I perceive the notion of difficulty is still evolving.

At the beginning, too, I was struck by a sense of how difficult it would be to try to uncover the meaning of difficulty for Biology 30 students. (This is not particular to the participants; it would have been difficult in any context.) An awareness of the difficulty of my research question brought with it, on the one hand, a sense of being challenged to persevere and succeed, and, on the other, an anguish that I would never be able to accomplish what I hoped to accomplish. Various people have told me, from time to time, that it seems that I like to make things difficult for myself. Maybe in choosing this topic I was again doing just that; and yet the challenge of it really appealed to me, drew me forward. I hoped beyond hope that I would be able to create something that fulfilled my aspirations. This sense of striving to fulfil as yet unfulfilled possibilities has been a powerful force that has beckoned me

onward throughout my thesis work, although in concrete terms it is impossible to explain what I hoped to achieve. Even now as I write this final chapter, my thesis appears to me somehow as a variety of possibilities. This was especially so in the early stages when I had little idea where the research would lead me. Rilke (1975) writes thus of an imaginary animal, "They fed it not with corn but with the possibility of being." It seems that I too fed my thesis with the possibility of being. As its form emerged the possibilities became lessened, yet the sense of unfolding is present even now.

I could list specific things that were difficult for me in regard to this thesis, for example writing about the meaning of difficulty for me (before the situational study), knowing what sorts of questions to ask in interviews, being told that what I had written was unacceptable, and pushing off the desire to address massive theoretical questions which were far beyond the scope of the present research. However, all of these were trivial compared to the deeper ongoing personal struggle and self-transformation which I have been experiencing, especially in later months. This has involved finding my way, my direction as a researcher, searching for an identity which suits me and with which I would feel comfortable.

There have been many times when I have felt almost unable to keep up with myself; I seem to have been changing so fast. Certain courses, readings, writing, discussions, influence my ideas and thoughts profoundly. Like an insect undergoing metamorphosis, I move ever onward from stage to stage. Yet, unlike an insect, I have the uneasy feeling that I do not know what or where I will be the following day. Also, unlike an insect whose metamorphosis eventually ends, I move onwards knowing that there can for me never be an end point, a butterfly that finally emerges and flies away. Because for me life will always consist of a constant moving

forward, a reaching beyond myself, laying down and traversing of new paths.

Rilke (1975) writes:

> "My most hopeful insight is, more or less, that a process of digging up the soil of my nature whereby the topmost parts get to the very bottom is going on."

I feel that I have and, to a lesser extent, still am experiencing this with regard to my graduate work in general but my thesis in particular. I perceive my thesis not only as a document concerning the experience of difficulty in biology classrooms but as a statement of self and my being-in-the-world at this time.

The last section of Chapter IV has been the most 'difficult' to write. It is there that I feel I have, to some extent, achieved what I set out to do. Through theorizing on difficulty as a mode of being I feel that I have come to know myself better, have begun to catch glimpses of my own grounds. It seems that what I have, among other things, been searching for is the very meaning of life. Looking at the notion of difficulty and its significance in life has helped me to come closer to the beginning of an awareness of what life means to me. I am tempted to say that within the topic lies a philosophy of life. Yet perhaps it would be more appropriate to say that a sense of what life is and how it should be lived has always lain within me and it is only through this thesis that I have begun to truly find myself.

The Beginning

So now my thesis is. There is something fearfully final in that statement, as if a door is being closed for the last time and yet I feel instead that all I have done so far is to open the door a crack, allowing a few rays of light to shine through. I am scarcely now beginning to ask what difficulty is in any meaningful way. Perhaps I have not even reached the point from which the question can be authentically asked. That is why what should 'officially' be the end is for me, and hopefully for others, too, just the beginning. All sorts of further questions or further ways of asking the same question beckon me onward. Thus I am invited to move beyond myself to the not-yet; I am called ever onward by life itself. It is this sense of beginning that draws me to Rilke (1975) when he writes:

> "I tell you that I have a long way to go before I am—where one begins. . .
> You are so young, so before all beginning and I want to beg you, as much as I can, to be patient toward all that is unsolved in your heart, and to try to love the questions themselves like locked rooms and like books that are written in a very foreign tongue. Do not now seek the answers, which cannot be given you because you would not be able to live them. And the point is to live everything. Live the questions now. Perhaps you will then gradually, without noticing it, live along some distant day into the answer. Resolve to be always beginning—to be a beginner." (p.25)

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APPENDIX I

COURSE OUTLINE FOR BIOLOGY 30

Unit 1 Functional Biology (about 75 hours)

1. Physical Properties of Cells

   a. Chemistry of Cells

      i. Review of background chemistry
      ii. Biochemistry of cells

   b. Physical processes

      i. Diffusion and osmosis
      ii. Active transport
      iii. Endocytosis and exocytosis
      iv. Enzyme function

2. Nutrition

   a. Autotrophic nutrition

      i. Absorption and transport of water, minerals and gases
      ii. Translocation of nutrients
      iii. Photosynthesis
      iv. Chemosynthesis

   b. Heterotrophic nutrition

      i. Alimentation
      ii. Absorption

3. Circulation in Animals

   a. Heart and blood vessels

   b. Blood and blood function

   c. Lymph and lymph function

   d. Control of circulation

4. Gas Exchange

   a. Mechanism of breathing

   b. Exchange and transport of gases

   c. Control of gas exchange

5. Cellular Respiration

   a. Energy release

      i. Aerobic respiration
      ii. Anaerobic respiration

   b. Energy utilization

      i. Muscular contraction
      ii. Absorptive activity
      iii. Electrochemical activity

6. Excretion

   a. Kidney function

   b. Body fluid balance

7. Metabolic Controls

   a. Genetic control of hormones and nervous responses

   b. Hormonal

      i. Plants
      ii. Animals

   c. Nervous

      i. Receptors
      ii. Conductors
      iii. Effectors

8. Human Reproduction

APPENDIX II

STUDENT PERCEPTIONS OF TOPIC DIFFICULTY IN THE BIOLOGY 30 CURRICULUM

This questionnaire is designed to determine which topics of the Biology 30 Curriculum you felt were most difficult. Before you rate the topics you studied, please fill in the following:

MALE ☐ FEMALE ☐ (tick the appropriate box)

List your High School Science courses completed since Grade 9 and currently being taken.

_____

_____

The Biology 30 curriculum has been divided into fourteen different topics. Some indication is given of subjects you may have studied within each topic. If you studied most of the subjects in the topic, rate that topic as easy, average or difficult by checking the appropriate box. If you only studied a few of the subjects (less than half), please check 'Not taught.'

1. Chemistry of Cells and Reactions

including: elements, compounds, chemical reactions, reversible reactions, nucleic acids, carbohydrates, fats, proteins, vitamins, oxidation, reduction.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

2. Physical Properties and Processes of Cells

including: parts of cell, nature of protoplasm, osmosis, osmotic pressure, diffusion, active transport, endocytosis, exocytosis, action and functions of enzymes.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

3. Transport, Translocation and Absorption in Plants

including: guard cells, stomata, transpiration, transport of water and minerals in xylem, absorption of water and minerals by root, transport of food in phloem, mineral nutrition-uses of essential and micro-nutrient elements.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

4. Photosynthesis

including: requirements for photosynthesis, pigments, chlorophyll, chloroplasts, structure of leaf, chemical reactions and equations, dark reactions, light reactions, raw materials.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

5. Heterotrophic Nutrition

including: structure and function of digestive system, digestive juices, enzymes, products of digestion, absorption of digested food, classes of foodstuffs eg.: carbohydrates, fats, proteins.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

6. Circulatory System

including, structure and function of heart, major blood vessels, arteries, veins, capillaries, blood pressure, blood flow.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

7. Blood: Composition and Functions

including: components of blood: red blood cells, white blood cells, platelets, plasma; functions of blood, eg.: oxygen transport, carbon dioxide transport, clotting, protection against disease; antigen-antibody reactions, blood types, lymphatic system.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

8. Gas Exchange

including: structure and functions of respiratory system, mechanism of breathing, eg.: diaphragm, ribs; control of breathing, gas exchange in lungs.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

9. Cellular Respiration

including: energy release, anaerobic respiration (fermentation), aerobic respiration, chemistry of respiration, ADP, ATP, phosphorylation, citric acid cycle, importance of cellular respiration.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

10. Energy Utilization

including: mechanical work, eg.: muscle contraction; electrochemical activity, eg.: transmission of nervous impulses; heat production, bioluminescence, absorptive activity of roots.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

11. Excretion by the Kidney

including: structure and function of kidney, formation of urine, filtration, reabsorption; body fluid balance—kidney as regulator of osmotic pressure and fluid volume, control of kidney by hormones.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

12. Hormonal Control

including: tropisms in plants, plant hormones, eg.: auxins, gibberellins, cytokinins, photoperiodism; hormones and glands in man, eg.: thyroid, parathyroid, Islets of Langerhans, pituitary, adrenals, gonads and their respective hormones.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

13. Nervous Control

including: sense organs, eg.: eye, ear, skin; structure and function of neuron, types of neurons, nerve impulses, reflex actions and reflex arc, spinal cord, brain, autonomic nervous system—sympathetic and parasympathetic systems, effectors, eg.: muscles, skeleton.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

14. Human Reproduction

including: structure and function of male and female reproductive systems; production of gametes, menstrual cycle, fertilization, implantation, pregnancy, birth.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

From the following list of topics in Biology 30 curriculum, select the five that you consider to be the most difficult. Rank your selections from 1 (most difficult) to 5 (least difficult).

Chemistry of Cells and Cell Reactions ____
Physical Properties and Processes of Cells ____
Transport, Translocation and Absorption in Plants ____
Photosynthesis ____
Heterotrophic Nutrition ____
Circulatory System ____
Blood: Composition and Functions ____
Gas Exchange ____
Cellular Respiration ____
Energy Utilization ____
Excretion by Kidney ____
Hormonal Control ____
Nervous Control ____
Human Reproduction ____

In a few sentences, please give your reasons for judging these topics to be difficult (i.e. what sorts of factors influenced your decision to rate a topic as difficult?).

_____

_____

_____

_____

_____

_____

What specific factors caused you to rank what you did as the most difficult topic? (i.e. What was it about that topic that made it so difficult?)

_____

_____

_____

_____

_____

APPENDIX III

A. Teacher Perceptions of Topic Difficulty in the Biology 30 Curriculum

This questionnaire is designed to determine which topics of the Biology 30 curriculum you feel your students find to be the most difficult. Before you rate the topics taught, please answer the following:

Is Biology 30 taught on a semester system or an all year system at your present school?_____

For how many years have you taught Biology 30?_____

The curriculum has been divided into fourteen different topics, some indication being given of subjects you may have taught within each topic. If a particular topic was not taught last semester/year, please indicate that in the appropriate space.

1. Chemistry of Cells and Reactions

   including: elements, compounds, chemical reactions, reversible reactions, nucleic acids, carbohydrates, fats, proteins, vitamins, oxidation, reduction.

   Easy ☐ Average ☐ Difficult ☐ Not taught ☐

2. Physical Properties and Processes of Cells

   including: parts of cells, nature or protoplasm, osmosis, osmotic pressure, diffusion, active transport, endocytosis, exocytosis, action and functions of enzymes.

   Easy ☐ Average ☐ Difficult ☐ Not taught ☐

3. Transport, Translocation and Absorption in plants

   including: guard cells, stomata, transpiration, transport of water and minerals in xylem, absorption of water and minerals by root, transport of food in phloem, mineral nutrition-uses of essential and micronutrient elements.

   Easy ☐ Average ☐ Difficult ☐ Not taught ☐

4. Photosynthesis

including: requirements for photosynthesis, pigments, chlorophyll, chloroplasts, structure of leaf, chemical reactions and equations, dark reactions, light reactions, raw materials.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

5. Heterotrophic Nutrition

including: structure and function of digestive system, digestive juices, enzymes, products of digestion, absorption of digested food, classes of foodstuffs eg.: carbohydrates, fats, proteins.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

6. Circulatory System

including: structure and function of heart, major blood vessels, arteries, veins, capillaries, blood pressure, blood flow.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

7. Blood: Composition and Functions

including: components of blood: red blood cells, white blood cells, platelets, plasma; functions of blood eg.: oxygen transport, carbon dioxide transport, clotting, protection against disease; antigen-antibody reactions, blood types, lymphatic system.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

8. Gas Exchange

including: structure and functions of respiratory system, mechanism of breathing, eg.: diaphragm, ribs; control of breathing, gas exchange in lungs.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

9. Cellular Respiration

including: energy release, anaerobic respiration (fermentation) aerobic respiration, chemistry of respiration, ADP, ATP, phosphorylation, citric acid cycle, importance of cellular respiration.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

10. Energy Utilization

including: mechanical work, eg.: muscle contraction; electrochemical activity, eg.: transmission of nervous impulses; heat production, bioluminescence, absorptive activity of roots.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

11. Excretion by the Kidney

including: structure and function of kidney, formation of urine, filtration, reabsorption; body fluid balance—kidney as regulator of osmotic pressure and fluid volume, control of kidney by hormones.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

12. Hormonal Control

including: tropisms in plants, plant hormones, eg.: auxins, gibberellins, cytokinins, photoperiodism; hormones and glands in man, eg.: thyroid, parathyroid, Islets of Langerhans, pituitary, adrenals, gonads and their respective hormones.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

13. Nervous Control

including: sense organs, eg.: eye, ear, skin; structure and function of neuron, types of neurons, nerve impulses, reflex actions and reflex arc, spinal cord, brain, autonomic nervous system—sympathetic and parasympathetic systems, effectors, eg.: muscles, skeleton.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

14. Human Reproduction

including: structure and function of male and female reproductive systems; production of gametes, menstrual cycle, fertilization, implantation, pregnancy, birth.

Easy	Average	Difficult	Not taught
☐	☐	☐	☐

From the following list of topics in Biology 30 curriculum, select the five that you consider to be the most difficult. Rank your selections from 1 (most difficult) to 5 (least difficult).

Chemistry of Cells and Cell Reactions ____
Physical Properties and Processes of Cells ____
Transport, Translocation and Absorption in Plants ____
Photosynthesis ____
Heterotrophic Nutrition ____
Circulatory System ____
Blood: Composition and Functions ____
Gas Exchange ____
Cellular Respiration ____
Energy Utilization ____
Excretion by Kidney ____
Hormonal Control ____
Nervous Control ____
Human Reproduction ____

In a few sentences, please explain the criteria you used for rating a topic as difficult for students.

_____

_____

_____

_____

_____

What specific factors caused you to rank what you did as the most difficult topic?

_____

_____

_____

_____

_____

B. Letter Sent to Biology 30 Teachers with Questionnaire

Department of Secondary Education
338 Education South
University of Alberta
T6G 2G5
September 24, 1981

Dear

I am a graduate student in Secondary Education, Biology Major, and am currently engaged in thesis research for my master's degree. My thesis is entitled 'Student Perceptions of Difficulty in High School Biology' and I am interested in discovering which topics of the Biology 30 curriculum both students and teachers perceive to be the most difficult and the reasons behind this.

In June, 1981, I administered questionnaires to 140 Biology 30 students in six high schools within the Edmonton Public School System. The format of the questionnaire was similar to the one I am presently enclosing with this letter. The aim of this part of my research is to compare teachers' and students' perceptions of difficulty in the Biology 30 curriculum. I am therefore sending this questionnaire to all Biology 30 teachers in the Public School system and would be most grateful if you could take a few minutes to fill it in and return it to me in the enclosed envelope as soon as possible. You are not required to place your name on the questionnaire as anonymity is guaranteed.

Thanking you in advance.

Yours sincerely

Valerie A. Oldham

VAO:lv

Encl.

C. Letter Sent to Biology 30 Teachers with Questionnaire

Department of Secondary Education
338 Education South
University of Alberta
T6G 2G5
September 25, 1981

Dear

I am writing to you for two reasons. Firstly, I wish to express my appreciation of your kind cooperation with my thesis research on 'Student Perceptions of Difficulty in High School Biology'. You may remember that I administered questionnaires to a class of your Biology 30 students in June. The results were most interesting and I now wish to compare them with teachers' responses on a similar questionnaire.

I am therefore sending a questionnaire to all Biology 30 teachers in the Edmonton Public School System and would be most grateful if you could take a few minutes to fill it in and return it to me in the enclosed envelope as soon as possible. You are not required to place your name on the questionnaire as anonymity is guaranteed.

Thanking you in advance.

Yours sincerely

Valerie A. Oldham

VAO:lv

Encl.

APPENDIX IV

QUESTIONS FOR INDIVIDUAL STUDENT INTERVIEWS

How do you perceive the various activities that go on in class, for example, working on objectives, lecture, audio-visual presentations?

Which do you prefer?

Why?

What is your opinion of the textbook?

Is it easy to understand?

Do you enjoy working from it?

What do you think of the way the objectives are stated in the unit?

Is this helpful to your learning or not?

If so, how?

What, if anything, have you found difficult about the cellular respiration unit?

Can you recall and describe a specific difficult experience?

When you say something is difficult, what do you mean?

What is it like to experience difficulty?

How does it make you feel?

What is it like to be confused?

Do you think cellular respiration is interesting?

Has there been anything discussed that really "hit home" and made sense to you (Perhaps something that you had previously wondered about)?

Do you think difficulty is related to interest or disinterest in a topic?

If so, how?

APPENDIX V

STUDENT AND TEACHER INTERVIEWS

A. Transcription of Individual Interview 5

Wednesday, 14 October, 1981

At the last minute, Student B had to attend a meeting at the time originally agreed for her interview. Therefore, she and Student A were interviewed together.

Int.: You've recently been studying a unit on cellular respiration and I'm interested to know how you found this unit. Student A, would you like to say something?

St.A: So far it's been a little bit difficult because there's so much material, so much to memorize and the different steps are confusing.

Int.: Student B, what do you think?

St.B: After photosynthesis, it was the same thing, you had to remember so much and with photosynthesis I was really confused and I had to get it in my mind. Now after I've done that, that's what makes respiration easier because you just take the same steps you did for memorizing it and stuff like that.

Int.: How do you feel about memorizing things?

St.B: I don't mind it.

Int.: You don't mind it?

St.B: I don't mind memorizing facts but memorizing the cycles gets a little tedious sometimes because you can forget a thing really easily or miss out things really easily because there's so much to remember. But it's not that bad.

St.A: I think memorizing just for the sake of memorizing isn't very good. If I can get at least parts of it from classroom work, then the rest sort of follows.

Int.: What sorts of classroom activities do you prefer and do you find most helpful? There seem to be quite a number of things that have been done recently like lectures, working on objectives, watching slide-tape presentations or films. In your photosynthesis unit you did a lab although you didn't do one in respiration. What out of those do you prefer?

St.B: Lectures.

Int.: You prefer lectures?

St.B: Since she talks to you about it. When you're reading it in the book you can read it and not understand it and not know what's going on here, but when she explains it, you can think, "I don't understand that. Why's that going on?" and you can ask and she'll tell you why. When you're reading the book you can't really ask it questions. If you don't understand it, there's not much else you can do about it.

St.A: In the lectures, too, you can ask questions and they may seem silly. She'll answer them and she doesn't make them seem silly, and the filmstrips are boring and monotonous more than anything.

St.B: That slide-tape presentation that we had on cellular respiration confused me more than it helped me because I didn't know anything about it and then we were kind of put in the situation and I was just kind of, "O no, what's going to happen next?" kind of thing. But if we would have had it at the end I would have understood it all. But because we had it at the beginning it was so confusing right at the beginning. I thought, "We have to learn all this?" but now that it's at the end I understand it all and now to see it, I could watch the film and understand what they are saying, too.

St.A: And they go so fast it's hard to pick out what facts you need because we're taking notes on them. It's really hard to pick out the things that you really need and sort them out from the things that, well, you really don't.

St.B: Yea, that's another thing. We knew nothing about cellular respiration right and you didn't know what was important and what wasn't important. I wrote down some really unimportant facts because I didn't know what. .

St.A: Right, and then you miss really important ones when you're trying to write it down quickly.

Int.: So what you're saying about that slide-tape presentation is that there was a lot of material presented?

St.A: Yea.

Int.: And it was presented fast so it was difficult to keep up with it?

St.B: Yes. I think we should have seen it maybe in the middle of cellular respiration not right, like we hadn't got any notes or anything.

St.A: We had our unit and we could have looked over the objectives, but we hadn't wrote anything from the books or anything so I found it really difficult.

Int.: Yea. How do you like working on your objectives individually?

St.A: I can go a lot quicker working by myself that I could working as a group, and I can get the material covered working from the book but half the time I can't understand some of it.

St.B: Yea.

St.A: And then you have to question anyway.

St.B: I think it's good that we do it by ourselves and you read it and you have to do some work for yourself and you kind of get the basic idea in your mind of what's happening and then when you don't understand it you can ask her. I think that's good because if she had to start from scratch it would take too long but if you get what's going on and then she can explain further or in more detail something you don't understand.

St.A: Yea, because with the people in class working at different rates and speeds the people who are working quickly are going to get bored if she has to go through everything and the other people, if she goes through really quickly are going to get lost. This is kind of a happy medium.

Int.: So you feel that working on objectives by yourselves is quite useful, do you?

St.A: Yea, well it gives you a chance to work and see what you can do and what you can find out on your own and then the things that, and see what you don't know more than what you know and then you can question her on that.

St.B: And I think it's good the way she just asks who doesn't understand what, so that people who didn't do the objectives can't just come to class and when she does them all just write down all the notes. They have to do them and try and understand them for themselves and that's probably what everybody finds difficult. If they did it and tried to understand it themselves and then she explained it to them, it's probably quite easy. It is quite easy. That's what I do and just ask certain questions if you don't understand, but if you don't do your objectives and you just come to school and then she starts talking, then you're kind of lost, too.

Int.: Do you think there are a lot of people who don't do the objectives?

St.A: Probably.

St.B: Yes, they figure they can get by on her giving the answers and you can't do that. No, you have to do them yourself.

St.A: I figure that if you do more work by yourself you're bound to understand more than if she just tells you everything. You can take in more if you're doing stuff on your own.

Int.: What do you think of the textbook? You have to use it when you work on your objectives.

St.B: I don't like it.

St.A: I don't like this textbook at all.

St.B: It's just that, I don't know, maybe we're not very good readers, but I find it really confusing, the way they explain things. You can understand, they explain it and they give you the definitions or something like that and you can write the definition down, you find it and everything, but understanding it is something a little different.

St.A: Sometimes it's almost like they're not getting right to the point, they go around things and they put in extra words that don't really need to be there and I don't like their glossary at all, the dictionary part in the back, it's not very explicit or anything. The textbook we had last year, I really liked that one in comparison to this one.

St.B: Yea, I do, too.

St.A: They've got things that you can understand and they don't have so many words that it's confusing and it had a really good glossary.

St.B: I know. I liked our textbook last year, too. Also last year we just had to read certain parts. We didn't have to read, 146 to 152; he usually, just those little parts. He'd just say, "Read this and this and this!" You were told exactly what to read. He never asked, he never had objectives, but he told you exactly what you had to read and you knew you had to know that part. When you read a chapter, you don't know which part you have to know and that's what the objectives are for, right, so that you, so it's the same thing really.

Int.: Can you think of any words to describe the vocabulary in the textbook?

St.B: Difficult.

St.A: University.

Int.: Do you feel it's, somebody described it to me as technical.

St.B: Yea.

St.A: In some ways it's technical but in other they are just, they use the larger words but they use them in such a way that it's

confusing. If you put it in a context where sometimes you get a self-explanatory, and they don't explain anything. They just say it and you're expected to understand it.

St.B: When I read the book I get all confused, like I always read it and then I get confused. Then I have to get Mrs. T. to explain it so I can get unconfused, so I don't like the textbook too much. It's good when you have to find out little specific things like what exactly does this do, or what happens exactly here, but for getting an overall general idea of what's going on, I don't think it's very good.

Int.: You mentioned, I think you both mentioned this idea of confusion. Can you tell me a little bit about what it's like to be confused; if, for example, you are reading through the textbook and it's confusing, what's happening?

St.A: Too many facts presented in too short a time and you, it's more like getting them in the wrong context and getting them mixed up.

St.B: Yes.

St.A: And if you've got a whole lot of things like the three processes we did, the glycolysis and the different ones, it's trying to figure out when they start and when they stop and when each happens and how they interrelate and where the interrelation occurs.

St.B: Yea, that's where I have problems is relating them to each other. Like I'm reading through and I understand this but I don't understand how it relates to this. I understand the one idea but I don't understand, I didn't understand how fermentation was involved and stuff like that, and I find that when you read through it you think "What am I reading? What does this mean?" Like that's what you sort of think and so then you go back and read it again and you think this means this and this means this, but why is this, and stuff like that. Sometimes I found you didn't understand it. You didn't ask the right questions either because you don't know what you're trying to understand. I know, I asked Mrs. T. a few questions and she kind of looked at me as if, "Are you talking about the same subject?" sort of thing, but I didn't understand it and so I didn't know exactly what to ask either so I was kind of out to lunch.

Int.: So, if something is confusing you, what you try to do is . .

St.A: Sort the facts out.

St.B: Yes

St.A: To see how they go with each other rather than individually and it's putting the facts together in the correct order sort of thing and not putting glycolysis at the end after something else happens and it can't happen because of something that happened.

Int.: So what happens if it is really very, very confusing? What happens to you mentally?

St.B: I guess you give up. You say, "I'll ask her tomorrow." You really think you don't understand it. I'm sort of getting nowhere and doing nothing and you figure trying to understand it makes no sense, so you say, "Well, I'll just put a check mark by this one and ask her tomorrow." That's what I always do.

St.A: Yea, procrastinate. Why do it now? You've tried and you've tried and there's no way you can understand it and I guess you just kind of have to go back to the basics. Everything's back to the basics and if you don't know the basics you're not going to know anything else. It's like that with every subject we've taken and sometimes you don't get taught the basics and they expect that you know in the next grade. It's really hard to understand then, to know where to begin.

St.B: Yea, if something's carried on from the year before and you're supposed to know that and either you did know it at one point in time and you forgot it, or you never did know it. It's hard to, if somebody assumes that you know that or assumes that it's already implanted in your mind, it's hard to, like when we were doing protein synthesis. I guess we were supposed to learn a lot of that in Grade 11 but we didn't learn any of that in Grade 11. She went over that really quickly because that wasn't really involved in her program, right, and you sort of had to think about it and you got confused and you thought, "Well, I'll think about that later because it's sort of confusing."

St.A: You don't want to worry about something you know you're not going to meet right away. You just sort of take it as it comes.

Int.: I've noticed that you both tend to ask a number of questions in class. When do you ask questions?

St.A: When I don't know something or I'm not sure about something or if I think it's right but yet I'm not sure maybe it's just for reassurance, then you know you're doing something right finally and maybe if that one's right then maybe you can get the next thing right.

St.B: You always ask, like today I kind of knew what she wanted but I didn't understand why she put it in that form of a question, so I asked her what the question meant, not really what the answer was because I knew what the answer was, but what the question meant. It just sort of clears up in your mind because in the question there's quite a few objectives as it is. You have to know what the question means to get the answer and so.

St.A: There's a lot of interpreting involved. You can take things different ways like, when it gets confusing.

Int.: Do you feel that cellular respiration is relevant to your everyday lives and do you feel that it's important that a unit should be able to be related in that way?

St.A: Well, I think so. I think it should be related because if you have no use for it, why study it? You don't really want to know it and I guess in this you're learning a little bit about your metabolism and how you work and how things around you work and if you get some sort of idea of that then you begin to appreciate things.

St.B: Yea, I think it should be in there because there's all things on diets and nutrition and stuff like that and that sort of has something to do with it, and the fact that fatty acids and glycerols and all the things like that are involved in it and you have to know how it works. I found it really interesting about, I'd always heard about lactic acid and how you're not supposed to get a build-up of lactic acid and I never knew what it meant really, just I knew I'd always heard the word. Then when I saw that, I thought, "That's pretty neat." I thought it was really interesting to understand what it meant exactly, what your body was doing.

Int.: What sort of effect do you think, if you feel that a unit is not very practical or you can't see any use for studying it, do you think that affects how you perceive it in terms of it being easy or difficult, or in terms of the amount of effort you're willing to put in?

St.B: Both. I think that if you don't think that it's practical, probably it's both related. You don't think it's practical because you don't understand it, it makes no sense how you're going to ever use this when you're older; so it's probably difficult and so you think it's unpractical and so you don't try very hard or you don't understand something so you think, "Well, what's the point of this?". So you think, "Well I don't care so I'm not doing it." I know that happens in math a lot, doing all those stupid equations that I'll never probably see again after I get out of Math 30, so you think, "What's the point really?" So you don't understand why you should have to do this, so it becomes more and more difficult and then when things get difficult you get frustrated and. .

St.A: Yea, and then you don't want to do it at all.

Int.: So it's kind of a two-way street?

St.B: Yea.

Int.: I asked you in class just today to write down or to describe for me an experience that you feel was difficult related to something in the cellular respiration unit. I'm wondering what sorts of things you wrote down.

St.A: Well, it was like finding in the processes when they began and when they end and how they interrelate and just trying to distinguish one from the other without completely mixing them up and being able to remember them, which part goes where and why they go together in the first place.

St.B: I thought that, like I said before, I didn't, for about two days there, I didn't understand how fermentation worked. I understood the end products was lactic acid and stuff like that, but I didn't understand why it happened or what caused it or how it fit into the cycle, the three ones. I thought, "Does this happen after?" It was just sort of confusing in my mind and I didn't understand how it fit in and stuff like that, and then I asked questions and I got the answers.

Int.: Does an experience seem difficult at the time or is it only in reflecting upon it that we can say it was difficult?

St.A: No, I think it's spur of the moment.

St.B: Yea, I think it's difficult at the moment then when you think about it and you get it in your mind, that really wasn't all that difficult afterwards.

St.A: It's hard to think back and say what's difficult and what's not. When something's difficult to me, it's difficult at the moment. I usually don't differentiate. It just happens. It's not something that you sit there and think about.

St.B: You know when you don't understand it and you think back and you think, "Well, I never did understand that," but it's because at the moment you never understood. I don't think it's when you look back and say, "That's what was really difficult, that's what was really hard to do."

St.A: That's what was hard about your question. I had to think, was it this or this? or why?

Int.: Yes, because you live through it without saying to yourself, "This is difficult."

St.A: Yes.

Int.: Without putting the concept of difficulty on it and so what essentially I was asking you to do was to try and go back to pull out an experience that, looking back, you feel was difficult and to describe that.

St.B: Actually, probably a lot of people put things that they still think are difficult, are things that are difficult to them now, not the whole week that we've been doing it, sort of as it's finishing they don't understand this and this and this, and that's

why it's difficult, probably not something that happened during the week because they probably understand it now.

Int.: So are you saying that difficulty is related to time?

St.A: Yes, it's just sort of at the moment it's difficult. You don't understand it, you get confused but then you can work it out so that it doesn't seem that difficult afterwards.

Int.: So something that presents a problem, say on Tuesday, by Thursday may not present a problem?

St.A: Yea.

Int.: Okay. That's great. Thank you.

B. Account of Individual Interview 5

Wednesday, 14 October, 1981

Student A felt that the unit was "a little bit difficult" due to the volume of material, eg. the different steps in the processes, which has to be memorized. Student B said this had been the same with the photosynthesis unit. She sounded somewhat ambivalent about memorization, saying it can get tedious at times, but "it's not that bad."

Student B likes lectures as she thinks it helps being able to ask the teacher where necessary. As she said, "when you're reading the book, you can't really ask it questions." The filmstrips or slide-tape presentations were not considered very useful for a number of reasons. A slide-tape presentation on cellular respiration was shown right at the beginning of the unit and because of this was confusing. Student A described them as going too fast and said that it is hard to pick out important things to write down, especially if little or no work has yet been done on the subject.

When asked about working on objectives from the textbook, Student A said she can generally get the material covered although she does not always understand it. Student B felt it was useful to do this by oneself before Mrs. T. lectured so that "you kind of get a basic idea of what's happening" and can ask questions. It enables students to work at their own speeds and to find out what they can and cannot understand. Student B likes the way Mrs. T. asks who understands and feels that those people who do not do their objectives can expect to have more difficulties than those who do.

Both students said they dislike the textbook. Student B described it as "confusing." Although one may be able to answer the objectives, "understanding is a little bit different." Student A expressed a dislike for the vocabulary used which she described as "university." Sometimes it confuses rather than clarifies, and this results in having to ask Mrs. T. to explain. Both students felt that the confusion arose with cellular respiration when they tried to interrelate the three separate appendices; for example, in trying to figure out how fermentation was involved. Student B said, "When you read through it, you think, 'What am I reading? What does this mean?' and you have to go back and read it again." Not understanding something makes it hard to ask the right questions in order to "sort the facts out."

When she is very confused by something, Student B figures that since she cannot understand it, she may as well leave it until the following day and ask Mrs. T. to explain. Student A spoke of procrastinating. They both agreed how difficult things can become if you don't know the basics in any subject. As an example, Student B mentioned protein synthesis which Mrs. T. went over really quickly due to it not being "involved in her program." Since it had not been learned last year, this was confusing.

Both students ask a number of questions in class (a large number compared to others in the class). They said they do this when they do not know something or are not sure about it. Student A pointed out that there is a lot of interpreting involved, hence things can be taken different ways, and sometimes this may lead to questions being asked.

Both students also feel that a unit should be related to one's everyday life and expressed the view that cellular respiration does this to some extent. The discussion of lactic acid had been found particularly interesting. Student B thought there was a two-way relationship between difficulty and relevance. For example, if something is difficult to understand, it may be perceived as impractical, and also if it does not seem relevant and one wonders, "What's the point really?" it may become increasingly difficult.

Both students felt that difficulty is experienced "at the moment"; that is why it is difficult to think back and remember a difficult experience. Student A said, "When something is difficult for me, it's difficult at the moment. It just happens. It's not something that you sit there and think about." Because the experience is lived through without being labelled as difficult, this makes describing such an experience problematic since you have to stand back and think, "Was this difficult or this?" Student B said she felt that a lot of students had probably written down things that they still feel are difficult, now at the end of the unit, rather than something that happened during the week. She said this would be because something that seemed difficult a few days ago may no longer seem difficult.

C. Transcription of Teacher Interview 5

Wednesday, 14 October, 1981

Int.: I'd be interested to know what sorts of things you feel I may be able to get from this study that would help you in some way. What sorts of things are you most interested in me finding out from your point of view?

Tea.: A couple of things. First of all specifically where students are finding the problems. I suspect that it's in the chemical reactions, in the reading of the chemistry. I'd like to know if it is indeed there and I'd also like to know how students feel explanations could be improved. Are they adequate? Are the explanations and is the class time that we've spent, is the learning package system, does that help any as compared to other types of biology classes that they've had in the past where they're just given reading assignments and asked to make notes. Does the narrowing down of the sorts of things I want and especially in terms of cellular respiration, does that help them in their reading and their understanding? So those two things; whether it actually is the chemical reactions and their interpretation that are causing the problems and how the teaching, the methods, really, if they're helpful at all or how they can be changed to be helpful to the students; because I myself have never interviewed the students themselves and asked them specifically where a problem was. I only know that the most of the questions arise springing directly from the reactions or there are repeats of questions that are really essentially have already been asked and are actually in the unit itself, like when Laurie asked about what are the starting products, what are the end products of the various, glycolysis, of Krebs' cycle, and oxidative phosphorylation. I really feel that that question did not need to be asked. I thought that it was spelt out. They had the chemical reactions right there. All they had to do was look. That seemed to me to be a very strange question to ask, considering we had already gone through the material. It seemed to me to be very clear-cut and concise. They all know what the starting material is and they all know what product means, so all they had to do was look and put it into words. Why was that question asked?

Int.: So am I right in thinking you feel you'd benefit from knowing, is it, the causes of the difficulties?

Tea.: Now I think causes, that would be individual; what are the difficulties.

Int.: The what?

Tea.: Now, yes, the what. Now the cause of the difficulty is individual, I think. Why is an individual student finding that difficult? They may find, the majority of the students may find, the same things

difficult but for different reasons, which will probably be personal—I would think their own background, their own mental capabilities, their own reading skills, their own powers of concentration. That, I think, is individual and that's not something that, I don't think, can be pinpointed in a very short span of time with thirty odd students, but you can concentrate on the areas that are difficult and how could those be made easier.

Int.: So you wouldn't say that the fact that there is so much biochemistry involved explains why they find it difficult? You wouldn't say that was a cause of it?

Tea.: No.

Int.: No. Are you saying that if you know the specific things that were causing difficulties for a number of students you would change your teaching, you would try to modify your teaching methods in order to overcome those difficulties?

Tea.: Certainly if enough students were experiencing the same types of problems, yes, I would change my entire classroom procedure. If only a few, I would hope to change individual explanations or the method in which I would give extra help to the individual. I can't see changing an entire classroom procedure unless the majority of students are all experiencing the same problems. I would try new methods. The only thing is how are you going to measure the success of those new methods? First of all we have to see how successful these students are on this exam. Now if they get a 60% average, that's not a bad average for a Biology 30 unit. Given the same group of students and a modification starting from fresh, would that change raise the average, would it help the understanding as measured by the test? So it's a difficult, difficult to measure.

Int.: So do we measure difficulty and how does it relate to achievement is, I guess, what we're asking.

Tea.: The only measure that we have is the test and comparing of several different classes over the same test. How does each class do? and then perhaps looking at how individual teachers teach them, but you're also talking then about individual students. One class is not going to be like the other class, so unless you get significant differences, 10%, between two or three different classes, then you might be able to pinpoint that a certain type of explanation, a certain method of teaching is more effective than another method of teaching.

Int.: Do you feel that it's possible that some students may think that cellular respiration is difficult and although they do well on their test, they will continue to think it is difficult or to think that it was difficult, or do you think that they are going to change their views of the difficulty in retrospect based on their test results?

Tea.: I think that's very likely. I think that a student that found it difficult, works really hard, gets a very good mark on the test is going to think, well maybe that wasn't as difficult as I thought it was.

Int.: Do you see any major differences between difficulty as experienced at the time or in a specific situation as opposed to difficulty on a test? Are we talking about the same thing?

Tea.: I don't think so. You're referring on the one hand to the learning process, on the other hand to the performance process already after having done the learning so I'm not too sure they can be compared, or not having done the learning in some cases.

Int.: Do you think it would be fair to say that in the context with which we're dealing with it that difficulties are experienced as part of learning or is the difficulty a difficulty in learning, in understanding?

Tea.: I don't see the difference between it as a part of learning or in learning.

Int.: No, okay, take them as the same but if we're talking about students having difficulties, does the difficulty have to be related to doing something? Does it have to be related to a what, what are they having difficulty with? I'm going round in circles here. This is very unclear in my own mind let alone trying to communicate it to you. Okay, it would seem to me that I can ask the students as I did this morning; I actually asked them to describe a difficult experience and what I got, which I'm not sure is exactly the same thing, was I got "I found it was difficult trying to fit those three appendices together and trying to see how they related to one another," things like that. I got the subject matter. What I'm wondering is, for example, let's take one of the overheads, the overhead that integrates the three appendices, what does a student have to be trying to do in order to say that he or she has difficulty with that particular subject matter? Is it not possible that the student could be given that overhead but unless he or she had the intent of doing something with it, namely of understanding it or of learning it, then it wouldn't necessarily be difficult?

Tea.: Well, okay, I think I get your drift. Of course, if you don't have to do anything it's not difficult.

Int.: So difficulty is always in trying to do something, in trying to achieve something.

Tea.: To understand or to memorize or to diagram or to explain. They're always trying, they have to do something, one of those things, interpret what's happening. If you give them the diagram and they look at it and they follow along, easy but ask, "You explain, you diagram, you memorize, how many ATPs, what is this part called?"

As soon as they have to understand, do something with it, then, yes, that is where the difficulty comes up. The just sitting there, the looking at it, that's not hard to do, the following along when somebody else is doing it. As soon as the onus is on the individual, it's your turn, it becomes difficult. You see we are the onlookers as students, we're looking, someone else is teaching, somebody else is doing or explaining and it becomes the same thing with a television set or in a crowd or listening to somebody else lecture. You're the passive person. It's not hard to sit there and be passive, but when you then are called upon to take some sort of action, be it mentally trying to comprehend, and that's an action, not necessarily. So yes, an activity has to be involved, some sort of an activity, just being passive, that's not difficult.

Int.: Where does one draw the line between a student sitting in the classroom although he or she is not outwardly doing anything, is following along, that you refer to or the keeping up with what is being said, are you saying that's a passive process?

Tea.: But you can't tell by looking at a person if the person is there comprehending or whether the person is watching but the mind is some place else. I'm saying that part of an activity of being involved is actually following along, trying to grasp what's going on, that's doing something, but you can't tell necessarily by looking at someone if they are actually following along and trying to comprehend or if they're just sitting there but none. . .they don't mean anything. You can only tell by questioning.

Int.: Do you feel that cellular respiration is inherently more difficult than most of the other topics in the curriculum?

Tea.: I'd say it's a little more difficult but the more I teach it the easier it becomes. That's because I'm more familiar with it than they are. So looking back I think that the more I'm going to be teaching biology, the more I have taught biology, the less apart I think the various units are in terms of difficulty. In other words, they're coming closer together. I think that other units are now becoming almost equally as difficult as respiration. So it's becoming less so in my view, but that's for me because I'm getting to be familiar with it.

Int.: So you don't feel that the very nature of the subject matter in the unit makes it necessarily or quite probably more difficult for the students?

Tea.: Not the nature of the subject matter but the way it's transmitted to the student; the fact that there is a lot of lecturing, the fact that there isn't a hands-on type of coverage of the material in the topic, that it is chemical reactions.

Int.: Is that not related to the inherent nature of the topic, that there are no suitable labs because of the type of material involved? Can the presentation be divorced from the nature of the topic? You see you said you felt it wasn't inherently difficult but you feel that one of the things that makes it difficult is the fact that it has to be presented in certain ways or can't be presented in other ways and I'm asking if those two things are not related.

Tea.: Yes, I suppose so. Okay then, the nature of the topic and how it's presented or different methods of presenting something; those two are related. If a topic can be made very, very practical in the idea that they can see or experience something, for example in the circulation unit, blood pressure, heart rate. Those are all things they can see and experience and therefore they're very easy to teach in the forms of demonstrations and labs as well as lecture. Cellular respiration is something that is a little more difficult to see and to demonstrate and therefore it's restricted in its presentation to lecture type and reading type presentations. So yes, the two would be related. Is that what you were asking?

Int.: Yes.

Tea.: Oh good (both laugh).

Int.: Yes, that was exactly what I was asking and that occurred to me before when you said something. I thought to what extent, you mentioned modifying or changing your teaching methods if necessary, etcetera, and I thought to what extent is that possible in view of the type of material.

Tea.: Right. When I'm thinking of changing teaching strategy that would mean things like questions, assignments, possibly taking a closer look at some labs which might help although I haven't run across any that would be of benefit in learning those chemical reactions. I mean the overall reaction is not that difficult and there are labs for that purpose but the specific chemical reactions, you need some very fancy equipment which schools certainly can't afford. So I would modify in my explanations, in assigning various types of questions to be asked and then to be taken up in class which would keep reinforcing the basic concepts brought in during the lecture, would force students to start using those concepts and that would help them to learn; so in those ways I would modify.

Int.: To what extent do you think what I asked the students to do this morning was impossible? I can't decide if it was because it was very difficult what I asked them to do, or if I didn't explain it very well. What I essentially asked them to do was to describe for me a difficult experience which they had had. Now to what extent is it possible to go back almost and relive?

Tea.: After the fact.

Int.: Yes, and to write about that.

Tea.: Okay. That, I'd say, would be part of the problem. First of all they have never probably thought about why something is difficult. They know what's difficult but they don't know why, and if they don't know why, then they can't put it down into words. Timewise, I mean it takes a while to sit down and think about why you thought something was difficult, so time might have been another big factor as well. It was just probably so much easier for them to write down very quickly what actual parts were hard rather than to think about why they were hard.

Int.: Yes, and how they experienced that hardness.

Tea.: Right, and possibly again after the fact, say their most difficult experience was several days ago and trying to recall that, trying to recall exactly how they felt, why they felt that way. It might not have stuck in their mind, the reasons for feeling that way.

Int.: Or even not the reasons, just what it was like. I remember yesterday in my talk with you, you were talking about how it felt to have to read over in the textbook.

Tea.: The frustration, yes.

Int.: With it not making sense. Now that was the sort of description that I had hoped to get from them.

Tea.: Right.

Int.: But which was not forthcoming.

Tea.: Right.

Int.: Because I felt if we. . .

The interview was interrupted at this point by a telephone call for Mrs. T. It was not resumed.

D. Account of Teacher Interview 5

Wednesday, 14 October, 1981

When asked what sorts of things from my study she felt could be useful to her, Mrs. T. gave two: firstly, specifically where students are finding the problems. She would like to know if it is, as she suspects, with the chemical reactions. Mrs. T. also expressed interest in knowing if students feel her explanations are adequate and if the overall approach she uses with the objectives is helpful. Therefore, this second consideration deals essentially with her teaching methods. Mrs. T. expressed the view that interviewing students about their difficulties could be beneficial since at present all she had to work from is the numbers and types of questions asked. One particular question from today's class had astounded her since she felt that it did not need to be asked due to having been explained previously.

Mrs. T. distinguished knowing what students found difficult from knowing why they had such difficulties. The causes of difficulty, she said, are individual, depending on such factors as student's background, mental capabilities, reading skills and powers of concentration; and cannot be pinpointed in a short space of time such as that involved in my study. She felt that, for example, the amount of biochemistry involved would not be described as a cause.

Mrs. T. stated that if enough students were experiencing the same types of problems, she would change certain aspects of her classroom procedure. However, she expressed concern with measuring the success of new methods, and suggested that if the present class of Biology 30 students achieved a 60% average this would be good enough. The question of how to measure difficulty was raised and Mrs. T. explained, "The only measure that we have is the test." The achievement of different classes on the same test could be compared using teaching methods as the variable, but those classes would obviously involve individual students. Mrs. T. felt that only if there were significant differences of 10% or more it might be worthwhile and possible to pinpoint the effectiveness of certain methods.

When asked if she thought there was a difference between difficulty as experienced at the time and difficulty as measured on a test, Mrs. T. said, Yes, and compared them in terms of the former being part of the learning process, the latter as part of the performance process.

Difficulty, it would appear, is always in doing something, for example, understanding, memorizing or explaining. As soon as the student him/herself has to do something with the material, "that is where the difficulty comes up." Mrs. T. felt that "just sitting there, for example looking at an overhead is not hard to do since somebody else is doing it She stated: "You see we are the onlookers as students, we are looking, someone else is teaching, somebody else is doing. . .You're the passive person." When that person is called to some sort of action, whether it be comprehension or something more physical, the difficulty may arise. When asked where to draw the line between the so-called activity and

passivity of a student, Mrs. pointed out that "you can't tell by looking at a person if the person is there," only by questioning them can one discern this. Thus, on the one hand, Mrs. T. seemed to be saying that being a student is a passive process since the teacher is doing, whereas on the other hand she said that comprehending could be seen as an action.

When questioned about the nature of the cellular respiration material, Mrs. T. said initially that she did not feel it to be its nature which makes it difficult for students but rather the way it is transmitted, for example, lectures and no labs. However, on further reflection on the relationship between these two aspects, she felt that they are related. Units such as circulation and blood are easy to teach because demonstrations and labs can be used, whereas this is not so when teaching cellular respiration. This led back to consideration of ways in which her teaching methods could be changed due to restrictions imposed by the nature of the material. Mrs. T. said that she could change questions, assignments and look again for possible labs.

Mrs. T. was then asked the extent to which she felt what I had asked students to do this morning was possible, namely to describe a difficult experience. She expressed the view that going back to such an experience could be problematic. "First of all, they have never probably thought about why something is difficult." If they don't know why, then they cannot write it down but may resort to explaining what is difficult instead. Time could have been another influencing factor since they only had ten minutes in which to do it, plus the difficult experience may have been a few days ago, hence this could also have made it even harder to recall "exactly how they felt, why they felt that way." Mrs. T. seemed to have interpreted my questions mainly in terms of why something was difficult, rather than what was it like to experience that difficult situation. She was reminded of her description yesterday of how it felt to have to read and re-read a particular part of the textbook, and I said I had hoped to have received similar descriptions from the students, but they had not turned out like that.

APPENDIX VI

BIOLOGY 30 UNIT ON CELLULAR RESPIRATION

Introduction

Green plants have the ability to assemble their own food by the process of photosynthesis. These organisms are, therefore, called autotrophic (auto meaning "self" and troph meaning "feeder"). Those organisms unable to manufacture their own food source are heterotrophic (hetero meaning "other"). They must ingest other organisms (plants or animals) in order to obtain energy and nutrients to meet their own physical requirements. First food molecules must be digested (hydrolysis) into small molecules that can be readily absorbed into the cellular cytoplasm. The oxidation of these molecules within the cell to release energy is the process of cellular respiration.

Objectives

Upon completion of the unit the student must be able to:

1. Define the following terms:
   a. ingestion
   b. digestion
2. State the four end-products of digestion and give their source.
3. Differentiate between anabolism and catabolism.
4. Define fermentation and give two examples of fermentation by living organisms.
5. Explain why fermentation yields only a minimal amount of energy.
6. Define cellular respiration and explain how it is typical of a redox reaction?
7. Relate the structure of an ATP molecule to its role as an energy source for cellular activities.
8. Describe the following reactions with reference to starting material, intermediate products, end-products, amount of ATP produced and location of reaction in cell:
   a. Glycolysis
   b. Kreb's Cycle/Citric Acid Cycle
   c. Oxidative Phosphorylation

9. Describe how glycolysis is similar to muscle fermentation and alcoholic fermentation.

10. Explain in which of the three reactions described in Objective #8, is the greatest amount of ATP formed and why.

11. Calculate the total number of net ATP molecules produced per glucose molecule degraded to CO_2 and H_2O.

12. State the overall formula for the complete oxidation of glucose.

13. Explain how molecules other than glucose may enter the cellular respiration pathway (for example: glycogen, glycerol, amino acids and fatty acids).

14. Briefly outline six uses of energy from the ATP molecule produced by cellular respiration.

Learning Activities

1. Read and make notes on the objectives from Biology (Kimball); pages 141-156.

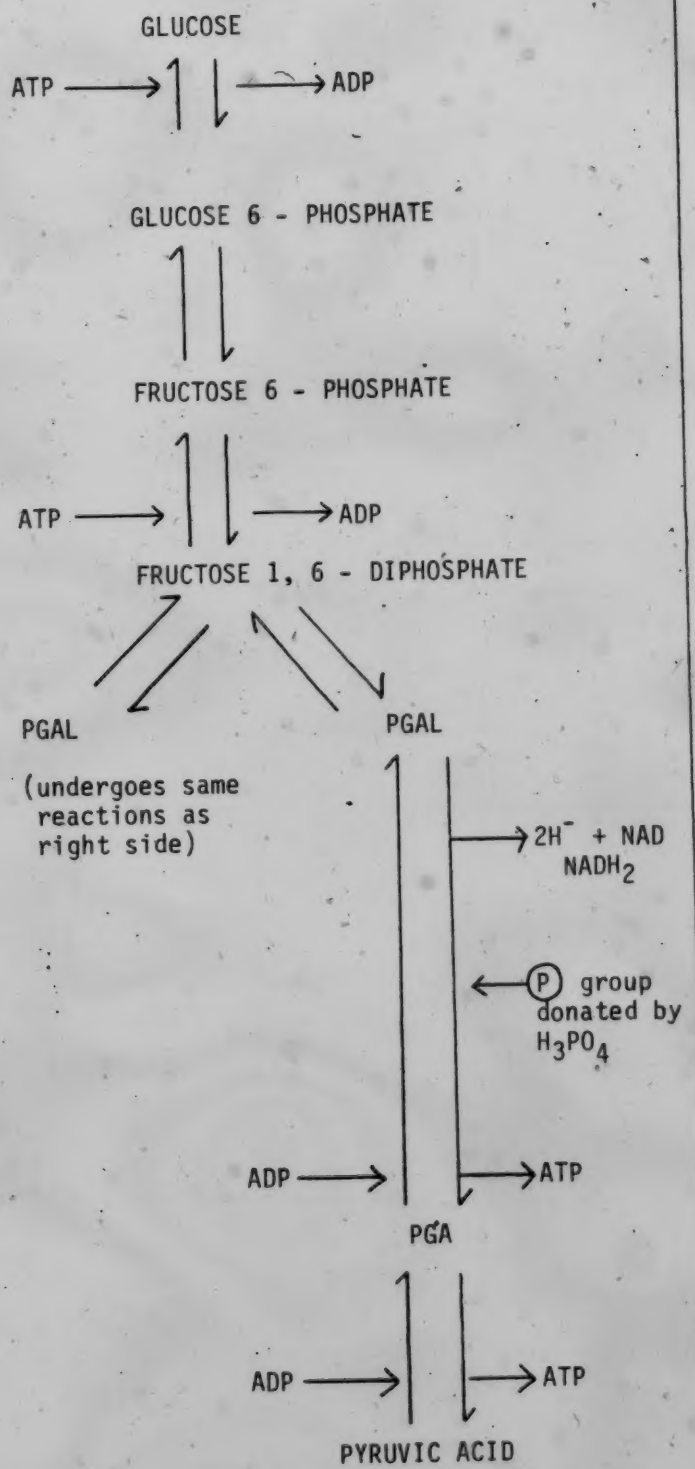
2. View the film(s) on this unit.

3. Attend the lecture on this unit.

4. Diagram from memory the pathway of cellular respiration.

5. View the slide-tape presentation: Cellular respiration energy for life, and make notes on the above objectives.

Glycolysis (in cytoplasm)



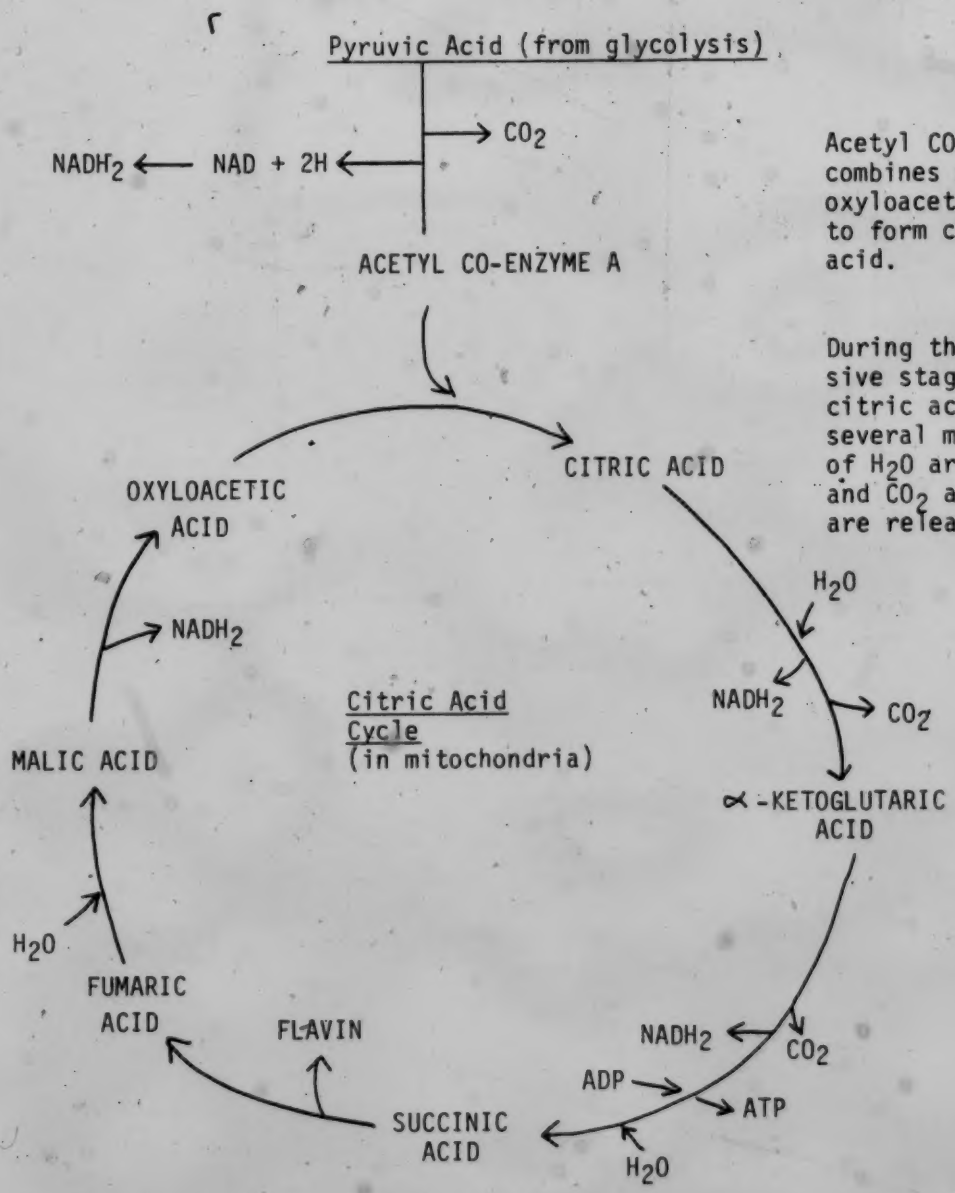
"Phosphorylation"

Glucose molecule is activated by the addition of a phosphate group and the energy of its bond.

Another P group is added. Fructose splits into two 3-carbon atom molecules called phosphoglyceraldehyde.

PGAL is oxidized (2H atoms are removed by NAD from each molecule of PGAL).

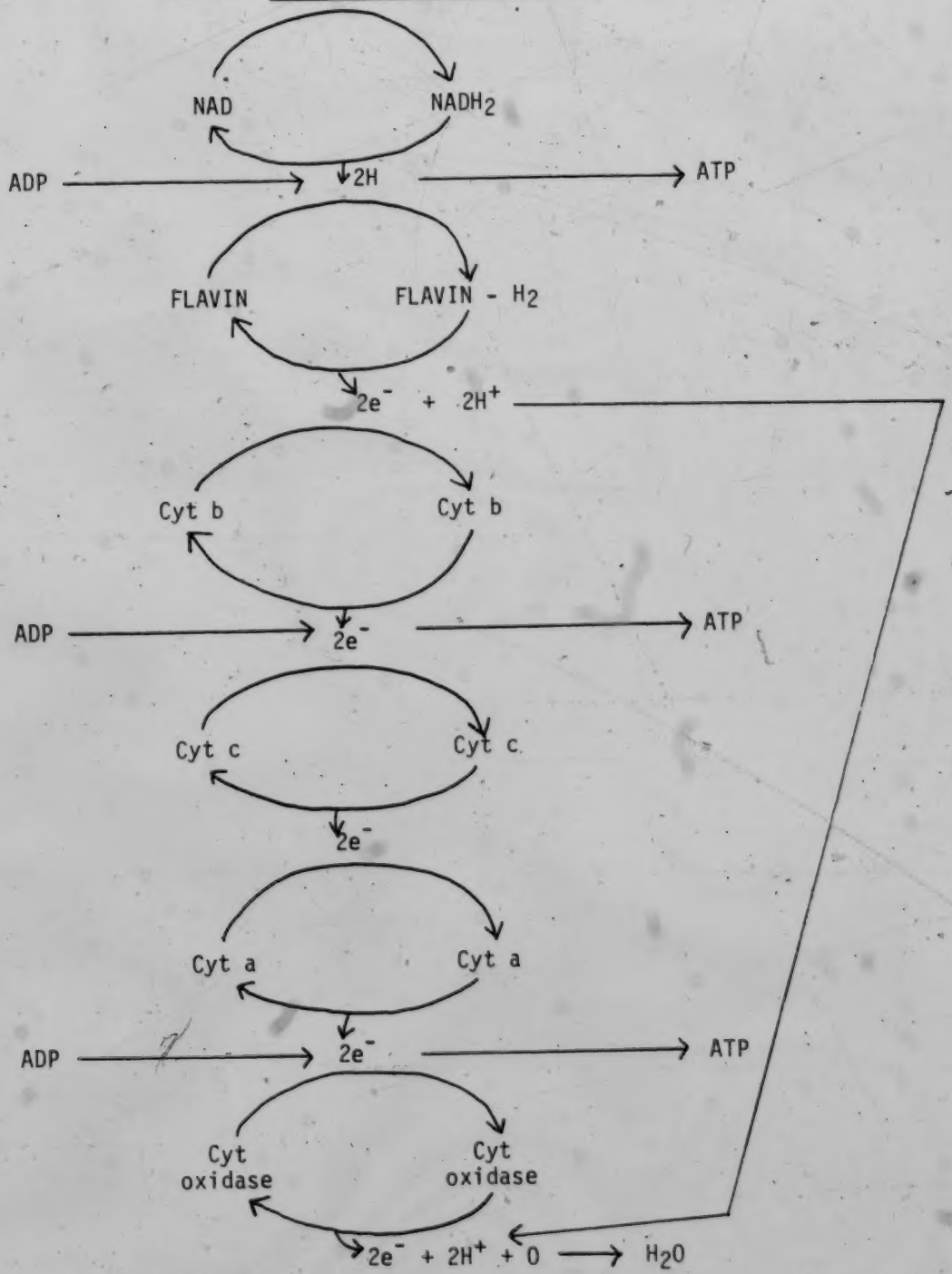
2 molecules of ATP are formed by removal of a phosphate group from each molecule of PGAL.



Acetyl CO-A combines with oxyloacetic acid to form citric acid.

During the successive stages of the citric acid cycle, several molecules of H_2O are added and CO_2 and H atoms are released.

The net results of the entire citric acid cycle show that for each molecule of glucose originally metabolized, 2 acetyl CO-A molecules enter into the citric acid cycle along with 6 molecules of H_2O. These are then degraded into 4 CO_2 molecules and 16 H atoms. During the entire citric acid cycle only 1 molecule of ATP is formed. Thus, for each molecule of glucose metabolized, 2 acetyl CO-A molecules pass through the citric acid cycle, each forming a molecule of ATP; or a total of 2 ATP molecules is formed.

Hydrogen Transfer System (in mitochondria)

- involves the cytochrome enzyme system
- the formation of ATP during the oxidation of H is called "oxidative phosphorylation".